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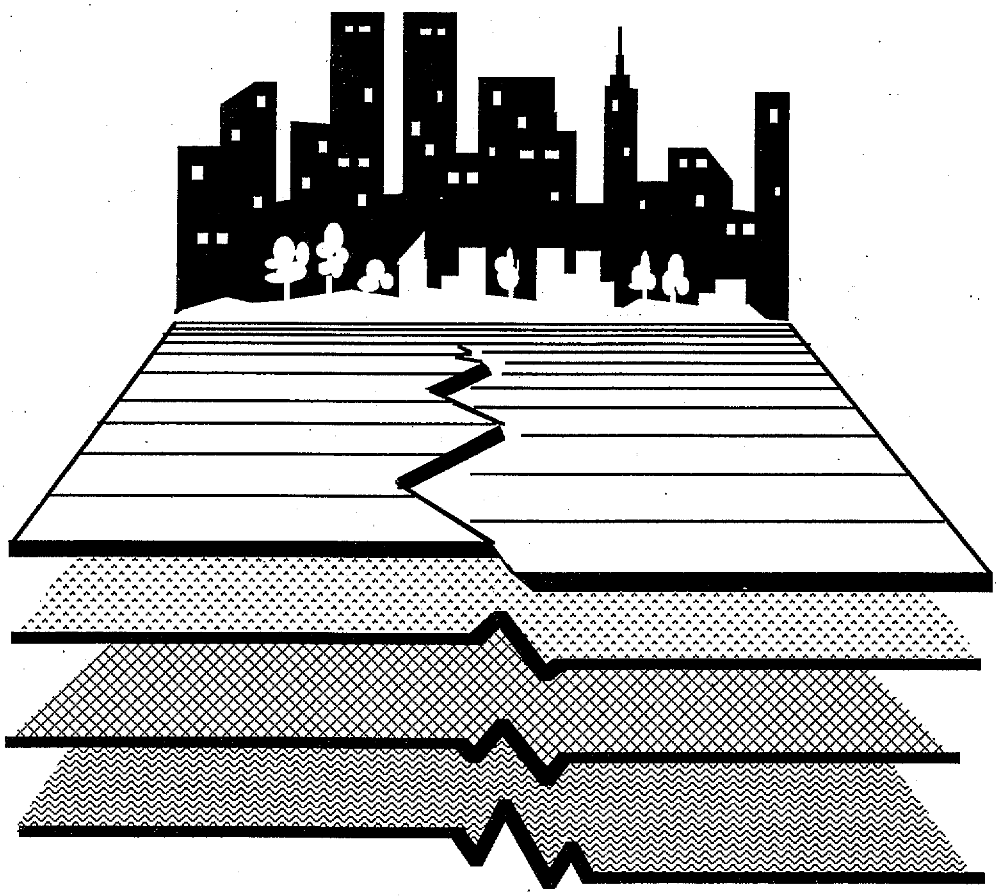
Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation



EARTHQUAKE HAZARDS REDUCTION SERIES 42

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Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation
EARTHQUAKE HAZARDS REDUCTION SERIES 42

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

ATC - 21-1

RAPID VISUAL SCREENING OF BUILDINGS FOR POTENTIAL SEISMIC HAZARDS: SUPPORTING DOCUMENTATION

ATC

APPLIED TECHNOLOGY COUNCIL
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Funded by
FEDERAL EMERGENCY MANAGEMENT AGENCY
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APPLIED TECHNOLOGY COUNCIL

The Applied Technology Council (ATC) is a non-profit, tax-exempt corporation established in 1971 through the efforts of the Structural Engineers Association of California. The purpose of ATC is to assist the design practitioner in structural engineering (and related design speciality fields such as soils, wind, and earthquake) in the task of keeping abreast of and effectively utilizing technological developments. To this end, ATC also identifies and encourages needed research and develops consensus opinions on structural engineering issues in a non-proprietary format. ATC thereby fulfills a unique role in funded information transfer.

The Applied Technology Council is guided by a twelve-member Board of Directors. The Board consists of representatives appointed by the American Society of Civil Engineers, the Structural Engineers Association of California, the Western States Council of Structural Engineers Associations, and two at-large representatives concerned with the practice of structural engineering. Each director serves a three-year term. Project management and administration are carried out by a full-time Executive Director and support staff. ATC calls upon a wide range of highly qualified professionals as consultants on specific projects, thus incorporating the experience of many individuals from academia, research and professional practice who would not be available from any single organization.

ATC DISCLAIMER

FEMA FOREWORD

The Federal Emergency Management Agency (FEMA) is pleased to have sponsored the preparation of this publication on rapid visual screening of seismically hazardous buildings. The publication is one of a series that FEMA is sponsoring to encourage local decision makers, the design professions, and other interested groups to undertake a program of mitigating the risks that would be posed by existing hazardous buildings in case of an earthquake. Publications in this series examine both engineering and architectural aspects as well as societal impacts of such an undertaking. They are prepared under the National Earthquake Hazards Reduction Program.

FEMA's program to mitigate the hazards posed by existing buildings was started in 1984 after resources appeared adequate to ensure the completion of a set of practical materials on the seismic safety of new buildings. The first project undertaken was the preparation of a *Plan of Action* and companion *Workshop Proceedings* by a joint venture consisting of Applied Technology Council (ATC), the Building Seismic Safety Council (BSSC), and the Earthquake Engineering Research Institute (EERI). The *Plan* included 23 priority items with a cost of about $40M and is being used as a "road map" by FEMA to chart activities and interpret, regroup, and expand projects in this area.

These activities will result in a coherent, cohesive, carefully selected and planned reinforcing set of documents enjoying a broad consensus and designed for national applicability. The resultant publications (descriptive reports, handbooks, and supporting documentation) will provide guidance primarily to local elected and appointed officials and design professions on how to deal not only with engineering problems, but also with public policy issues and societal dislocations. It is a truly interdisciplinary set of documents, even more so in concept and scope than the set related to new buildings.

Completed in the spring of 1988 were:

- The first collection of costs incurred in seismic rehabilitation of existing buildings of different occupancies, construction, and other characteristics, based on a sample of about 600 projects;

- A handbook (and supporting documentation) on how to conduct a rapid, visual screening of buildings potentially hazardous in an earthquake (ATC-21 and ATC-21-1 reports); and

- A report on the state-of-the-art of heavy urban rescue and victim extrication (ATC-21-2 report).

In preparation are:

- A handbook (and supporting documentation) on consensus-backed and nationally applicable methodologies to evaluate in detail the seismic risk posed by existing buildings of different characteristics (ATC-22 and ATC-22-1 reports);

- An identification of consensus-backed and nationally applicable techniques for the seismic-strengthening of existing buildings of different characteristics and a methodology to estimate their costs, with supporting documentation; and

- A handbook on how to set priorities for the seismic retrofitting of existing buildings—a truly interdisciplinary examination of the complex public policy-societal impacts of retrofitting activities at the local level.

In competitive procurement is:

- An identification of existing and realistically achievable financial incentives in the public and private sectors derived with the assistance of a user group and disseminated in selected localities cooperating in the effort.

Additionally recommended actions are:

- Cost benefit analyses to determine the costs and benefits resulting from rehabilitating selected types of buildings with selected occupancies in a number of cities in different seismic zones. They will build on all the engineering and societal information developed or being developed by the ongoing projects relating to existing buildings. Output will provide findings and recommendations in both strictly economic terms and also in societal and public-policy-related terms.

- A set of nationally applicable and consensus-approved guidelines for the seismic rehabilitation of existing buildings based on acceptable performance and other overarching criteria for strengthening buildings, and on the information developed in the other handbooks and supporting engineering reports described earlier. Reflected in the guidelines will also be the latest research results and technical lessons learned from recent earthquakes.

- Complementary materials to encourage the use of the recommended guidelines similar to those developed for new buildings.

- Information dissemination for existing hazardous buildings, to be modeled after and grafted onto the existing BSSC project of information dissemination on new buildings.

ACKNOWLEDGMENTS

With respect to this publication, FEMA gratefully acknowledges the expertise and efforts of Dr. Charles Scawthorn, the principal author, his staff and consultants, the Project Engineering Panel, Technical Advisory Committee, and the Applied Technology Council management and staff.

FEMA NOTICE

The report was prepared under Contract EMW-86-C-2359 between the Federal Emergency Management Agency and the Applied Technology Council.

For further information regarding this document, or additional copies, contact the Federal Emergency Management Agency, Earthquake Programs, 500 "C" Street, S.W., Washington, D.C. 20472

PREFACE

In April 1987 the Federal Emergency Management Agency (FEMA) awarded the Applied Technology Council (ATC) a 1-year contract to develop a handbook on rapid visual screening of seismically hazardous buildings. The intent of the handbook is to provide a standard rapid visual screening procedure to identify those buildings that might pose potentially serious risk of loss of life and injury, or of severe curtailment of community services, in case of a damaging earthquake.

As the initial step in the development of this handbook, ATC evaluated existing procedures and identified a recommended rapid screening procedure. Included in this report are the results of this initial effort: (1) a review and evaluation of existing procedures; (2) a listing of attributes considered ideal for a rapid visual screening procedure; and (3) a technical discussion of the recommended rapid visual screening procedure. Also included as appendices are sample data entry forms for existing procedures and other supporting information.

Dames & Moore, San Francisco, California, a consulting firm with experience in the seismic evaluation of existing buildings, served as the project subcontractor. Charles Scawthorn, formerly with Dames & Moore and currently with EQE, Inc. San Francisco, served as Principal Author. He was assisted by Thalia Anagnos of San Jose State University. Members of the Project Engineering Panel who provided overall review and guidance for the project were: Christopher Arnold, Maurice R. Harlan, Fred Herman, William T. Holmes, H. S. Lew, Bruce C. Olsen, Chris D. Poland (Co-Principal Investigator), Lawrence D. Reaveley, Christopher Rojahn (Principal Investigator), Claire B. Rubin, Howard Simpson, Ted Winstead, and Domenic A. Zigant. Members of the Technical Advisory Committee, who reviewed the handbook from the user perspective near the close of the project, were: John L. Aho, Brent Ballif, Richard V. Bettinger, Patricia A. Bolton, Don Campi, Laurie Friedman, Terry Hughes, Donald K. Jephcott, Bill R. Manning, Guy J. P. Nordenson, Richard A. Parmelee, Earl Schwartz, William Sommers, Delbert Ward and Dot Y. Yee. Joann T. Dennett served as Technical Communication Consultant. The affiliations of these individuals are provided in Appendix D.

ATC also gratefully acknowledges the participation of the following individuals: Ugo Morelli, FEMA Project Officer, for his valuable assistance, support, and cooperation; Allan R. Porush, William E. Gates, Mike Mehrain and Ronald T. Eguchi of Dames & Moore for their review comments; Sandra Rush of RDD Consultants and Michele Todd of ATC for preparing the final manuscript; and Tom Sabol of Englekirk & Hart, for checking scores presented in Appendix B.

Christopher Rojahn
ATC Executive Director

SUMMARY

This is the second of a two-volume publication on a methodology for rapid visual screening of buildings for potential seismic hazard. A detailed description of the recommended procedure for identifying potentially hazardous buildings, including information to aid the field surveyor in identifying structural framing systems, is contained in the companion ATC-21 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (ATC, 1988).

A literature review of existing procedures for rapid visual screening of buildings for potential seismic hazards showed that few rapid screening methods exist in the literature, and that none has widespread application. A survey of practice indicated that present earthquake structural engineering practice may often involve an engineer conducting a "walk-through" survey of a building, but engineering practitioners appear to rely on extensive experience and judgment rather than any formal procedure. Although some rapid visual studies have been performed, mainly in California to identify unreinforced masonry (URM), these are not well documented in the literature.

The literature search and a review of surveys conducted by communities indicated that a satisfactory rapid visual screening procedure does not presently exist. A satisfactory rapid visual screening procedure would include the following attributes: (i) explicit definition of the expected ground motion (i.e., the "earthquake loading"); (ii) consideration of all major building types, not just one or two; (iii) a procedure whereby the degree of seismic hazard is quantitatively determined, thus permitting priorities to be set with regard to mitigation planning and detailed investigations of the most potentially hazardous buildings; (iv) a rational, analytically based framework for this quantitative procedure (in which weights or factors are not arbitrary), whereby the quantitative results relate to physical quantities and have a physical interpretation; (v) ability to be used nationwide and to account for local variations in building practice, loading levels, and site conditions; (vi) recognition and incorporation of probabilistic concepts, to permit treatment of the inherent uncertainties in attempting to identify building types and characteristics; (vii) incorporation of such factors as building age and condition; and (viii) background reference material illustrating building types, various structural hazards and related information.

This report presents a recommended procedure incorporating these attributes. It is based on a Basic Structural Hazard score, which equals the negative logarithm of the probability of major damage, with major damage defined as 60% or greater of the building's replacement value. Values of the Basic Structural Hazard score for 12 building types are determined for the National Earthquake Hazards Reduction Program (NEHRP) (BSSC, 1985) Map Areas 1 to 7, using data from ATC-13 (ATC, 1985). Modifiers on this score are also presented, based on the collective opinion of the Project Engineering Panel and other engineers nationwide for important seismic performance-related factors such as age, poor condition, and soft story. The procedure can be implemented in the field by use of a standard clipboard form, including a field photo and sketch of the building. Information to aid the field surveyor in identifying the appropriate building type and assigning a Basic Structural Hazard score and modifiers, are provided in the associated handbook, (ATC, 1988).

GLOSSARY

AF	Assessor Files
ABAG	Association of Bay Area Governments
ATC	Applied Technology Council
BF	Braced frame
BSSC	Building Seismic Safety Council
BW	Bearing wall
CF	Concrete frame
CSW	Concrete shear wall
CSWF	Combined shear wall, moment resisting frame
EERC	Earthquake Engineering Research Center
EQ	Earthquake
FEMA	Federal Emergency Management Agency
GNDT	Gruppo Nazionale per la Difesa dai Terremoti
HOG	House over garage
LB	Long Beach
LM	Light metal
MH	Mobile home
MMI	Modified Mercalli intensity
MSW	Masonry shear wall
N/A	Not applicable
ND-RC	Non-ductile reinforced concrete
NEHRP	National Earthquake Hazards Reduction Program
NISEE	National Information Service for Earthquake Engineering
NSF	National Science Foundation
PEP	Project Engineering Panel
P/F	Pass/fail
RC	Reinforced concrete
RM	Reinforced masonry
RSP	Rapid visual screening procedure
S	Structural Score
Sbn	Sanborn maps
SMRF	Steel moment resisting frame
SF	Steel frame
SW	Shear wall
TU	Tilt-up construction
UBC	Uniform Building Code
URM	Unreinforced masonry
W	Wood building, any type
WF	Wood frame

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1
INTRODUCTION

This report, sponsored by the Federal Emergency Management Agency (FEMA), reviews the literature and existing procedures on rapid visual screening in order to determine a recommended procedure as a first step toward the development of a handbook on the rapid visual screening of buildings for potential seismic hazards. The intent of the Handbook, which will be referred to as the *ATC-21 Handbook* (ATC, 1988), is to provide the target audience with a standard rapid visual screening procedure to identify those buildings that might pose potentially serious risk of loss and life and injury, or of severe curtailment of community services, in case of a damaging earthquake.

A rapid visual screening procedure (Rapid Screening Procedure, abbreviated RSP) is a methodology that, with associated background information, would permit an individual to visually inspect a building and, by obtaining selected data, to arrive at a decision as to which buildings should be further studied by an experienced professional engineer who would conduct a more in-depth review of the seismic capacity using structural drawings, design calculations, and perhaps inspecting the structure itself. The RSP inspection and decision-making process typically would occur on the spot, with perhaps two to four "average" buildings being reviewed per person-hour (i.e., 15 to 30 person-minutes per building). The personnel doing the rapid screening would typically not be experts in earthquake performance of buildings, but rather building inspectors, technicians or junior engineers.

Visual inspection would be a "sidewalk survey" done from the street, without benefit of entry to the building and without access to the structural drawings or most other supplementary information. In some cases, general structural general structural system-related information may be available to the inspector via building department or tax assessor files. (Note, however, that experience has shown the latter often to be unreliable with regard to structure information.) In effect, the inspector would note the dimensions of the building, its occupancy, structural materials and systems, condition, and other information. This information would be entered onto a form (on a clipboard or electronically), and employed in algorithms to determine a seismic hazard ranking for that building.

The RSP would be the first step of a two or more step process, in which ideally the RSP would permit (i) identification of those buildings that require additional, more detailed investigation by qualified engineers, and (ii) prioritization of the buildings to be further investigated, so that technical and other resources could be most effectively utilized.

It should be emphasized that any RSP is by definition a very approximate procedure, which will almost certainly fail to identify some potentially seismically hazardous buildings. The goal is to broadly identify *most* of the potentially seismically hazardous buildings, at a relatively modest expenditure of time and effort, and to eliminate *most* of the relatively adequate buildings from further review. Lastly, an RSP is a methodology intended for rapidly evaluating the hundreds or thousands of buildings in a community. It is *definitely not* intended for the full determination of the seismic safety of individual buildings.

The target audience for the *ATC-21 Handbook* includes:

- local building officials
- professional engineers

- registered architects
- building owners
- emergency managers
- interested citizens

Any or all of these people might be involved in efforts to identify a community's seismically hazardous buildings and mitigate the hazard. It is recognized, however, that building inspectors are the most likely group to implement an RSP, and this group is considered the primary target audience.

This report identifies, reviews, and critiques those RSP's currently or previously used to evaluate seismically hazardous buildings. For each method the following is provided:

- a description and discussion of technical advantages and disadvantages, including suitability of scope and format, and costs of implementation
- impacts and implications of regional variations in construction practices and seismic loading levels
- suitability for use by each segment of the target audience
- the general level of uncertainty inherent in its use

Three main sources for identifying existing procedures were used:

- the technical literature
- discussions with jurisdictions and communities that have performed or attempted a survey of their seismically hazardous buildings
- practicing professional engineers who are called upon to provide opinions as to the seismic hazard of a building or other structures. (Prominent engineering firms have performed rapid screenings of hundreds of buildings.)

Technical literature was identified by electronic data retrieval (i.e., the Engineering Index, accessed via Dialog); citations furnished by the ATC-21 Project Engineering Panel; review of the National Information Service for Earthquake Engineering (NISEE) holdings at the Earthquake Engineering Research Center in Richmond, California; and information and references in the author's files.

There exists an extensive body of literature on methods of seismic analysis and/or review of existing buildings. However, most of these methods are simplified or more or less detailed engineering analysis procedures, involving computations of seismic demand and capacity, often with the benefit of the structural plans or similar detailed privy information. Although some of these methods contain an initial rapid visual screening element, most do not. Therefore, only those methods that explicitly have a rapid visual screening element have been reviewed herein, and no attempt has been made to review the much larger literature of seismic evaluation of existing buildings.

Following this first section, the remainder of this report consists of the following chapters:

Chapter 2: Definition of an ideal rapid visual screening procedure, against which existing methods are judged

Chapter 3: Summary of each of the RSP's identified

Chapter 4: Presentation of the evaluation criteria used in this project and a detailed evaluation of the following aspects of the RSPs reviewed herein:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

Chapter 5: Recommended procedure for rapid visual screening of buildings for potential seismic hazards

Lastly, the appendices include typical data sheets employed in several of the surveys reviewed; an explanation of the determination of the Basic Structural Hazard scores and modifiers; the criteria for selection of a cut-off Structural Score; and a list of the ATC-21 project participants.

2
ATTRIBUTES OF AN IDEAL RAPID VISUAL SCREENING PROCEDURE

In order to evaluate existing RSP's, a set of criteria is required against which present RSP's can be judged. In this chapter, the attributes of such an "ideal rapid visual screening procedure" are presented. These ideal attributes have been determined based on a review of rapid visual screening procedures, as presented in the following sections, as well as the general experience of the project participants in conducting numerous field surveys and analyses of existing buildings. No single, currently available RSP satisfactorily incorporates all of the attributes indicated below.

Applicability to All Building Types: A rapid visual screening procedure for identifying seismically hazardous buildings should provide an initial assessment of the seismic hazard of individual buildings and therefore it should not be limited to one type of building structure. Rather it should be capable of identifying hazardous buildings of all construction types. For example, many rapid visual surveys have been limited to identifying unreinforced masonry (URM) structures, based on the assumption that these are the most hazardous buildings in the community. Although URM hazards have thus been identified, other (sometimes greater) hazards, for example, related to older tilt-up or non-ductile concrete buildings, have gone uncounted. Should the need arise, an RSP could be applied to only one structural category. However, all building groups should receive at least an initial limited-sample test screening in a portion of the community, to verify assumptions of which building type is the most hazardous. If these assumptions are verified, then selected building groups/areas may be targeted, for reasons of economy. The situation of, for example, identifying all unreinforced masonry buildings and having no idea of the seismic hazards in the non-ductile reinforced concrete building group, or the house-over-garage building group, should be avoided.

Quantitative Assessment: Assessment of the hazard should be quantitative as it not only permits pass/fail decisions, but also provides a ranking system that may be used to set priorities within the "failed" category. A quantitative scheme also has the advantage of assuring a more uniform interpretation of the weights of "structural penalties" by survey personnel.

Nonarbitrary Ranking System: Although several of the studies reviewed do include quantitative approaches, these scoring systems are arbitrary and provide relative hazard assessments rather than an estimate of actual hazard based on physical parameters. A quantitative ranking system, which is useful for ranking structures for hazard abatement, should be nonarbitrary to avoid misleading results. The scores should be rationally based, and include uncertainty when possible. Their development should be clear so that new data can be incorporated as they become available and so that the scores can be modified for local building conditions.

Supplemental Information: As much as possible, supplemental information from building department and assessor's files, insurance (Sanborn) maps, previous studies and other sources should be collated and taken into the field in a usable format, for verification as well as to aid field personnel. Ideally, these data should be in a form so that information can be easily attached to each survey form as it is completed (e.g., a peel-off label or a computergenerated form, with part identifying the building and containing pre-field data, and part to be filled out in the field).

Earthquake Definition: An important attribute is that the earthquake loading against which the capacity of the building is being judged be defined explicitly, preferably in physically based units such as acceleration. Otherwise it is unclear what "earthquake" loading the structures are being judged against and, further, the RSP is limited in its application to the region for which it was developed. Structures will have different damage potential in regions with different seismicity; thus a clear definition of the seismic demand should be included. Although a few of the available methods do include some explicit earthquake definitions, in most of these it is in the form of Modified Mercalli Intensity or Uniform Building Code zone. The complex questions of what earthquake loading a building should withstand and what the "acceptable risk" should be often require iterative solutions; therefore, it is possible that a re-screening could occur at a later time. Thus sufficient building-specific data should be recorded to permit adjustments should the input earthquake data be modified.

Data Collection: Organization of the data is an important part of an RSP. Specific details of structural type and configuration, site conditions, and non-structural aspects should be in a checklist format to avoid omissions. The data collection form should provide space for sketches, photos, and comments and should systematically guide personnel through the data recording procedure. Sketches and photos are invaluable for later reference. Both should be an integral part of the field data recording, because they are complementary. (A photo is data intensive, whereas a sketch emphasizes selected features, such as cracks, that may not be easily discernible on a photo of an entire building. In addition, requiring a sketch forces the surveyor to observe the building in a systematic fashion.)

Systematic and Clear Criteria: It is essential that an RSP, and the decisions deriving therefrom, be based on well-documented criteria and that "judgment" decisions be minimized. Although it is anticipated that survey personnel will have some interest in the elements of earthquake behavior of buildings and be capable of making subjective decisions when necessary, they should be provided with extensive written guidelines to avoid differing interpretations of the criteria for identifying hazardous buildings. Documentation should include many sketches as well as "inferences," or rules, to assist personnel in making decisions when information is uncertain.

Age: Age should be explicitly recorded. Often unavailable, age can be estimated, usually within a decade or two, on the basis of architectural style. Age can indicate whether a building is pre- or post- a specific "benchmark" year in the development of seismic codes for that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building was built before 1948, it is likely that it is unbolted. These benchmark years differ by jurisdiction, but usually are locally known or can be determined.

Condition: State of repair is an important factor in seismic performance, and should be required to be noted, as it forces the survey personnel to look for problems such as cracks, rot, and bad mortar. Where relevant, this would include previous earthquake damage. Additionally, renovation should be noted, where possible. Renovation can be positive, because it indicates increased investment (which may have led to improvements in the structure), and/or negative, when it masks the true age of the structure. Additionally, renovation may have resulted in the removal and/or alteration of important structural members and thus may affect seismic performance. A common example is the "addition" of loading doors by saw-cutting of walls in tilt-up buildings, which actually removes seismic resistance.

Occupancy: Occupancy should be noted, as it is a factor in overall risk and may be required for subsequent decision making. How it will be factored into seismic hazard decision making is sometimes a difficult question. In some of the surveys reviewed, buildings were classified into high, medium, and low risk categories depending on the occupancy. This information was then used to rank the hazardous structures.

Configuration: Configuration issues should be noted and their contribution to the hazard quantified. It is clear from past experience that structural irregularities can be significant in the performance of a building during an earthquake. Many of these issues have been identified by Arnold and Reitherman (1981), and include items such as soft story, vertical and/or horizontal discontinuities, and irregularities of plan.

Site Aspects: Site aspects such as potential pounding between buildings, adjacent potentially hazardous buildings, corner buildings, and soil conditions need to be noted and quantified. By quantifying poor site conditions as "penalties," the survey personnel will have a uniform interpretation of the importance of each of the issues in the performance of the building.

Non-structural Architectural Hazards: Earthquake damage to building ornamentation or exteriors can lead to significant damage and/or life-safety hazard. Common examples include the fall of parapets, chimneys, and other overhanging projections.

Personnel Qualifications: Personnel background and training may prove critical to the results of an RSP. An ideal RSP should rely as little as possible on the need for extensive technical education or experience on the part of the personnel involved. Ideally, technician-level individuals (high school plus one to two years equivalent education/experience) should be able to perform the RSP, after one or two days of specialized training.

Hazard Analysis Scheme: Finally, for an ideal RSP the scheme for combining scores to identify the degree of seismic hazard for a building structure should be simple and fast, involving little or no field calculations beyond simple arithmetic.

The following chapters first present a summary of each of the RSP's identified, then evaluate them against the above "ideal" attributes, and finally, present a recommended procedure.

3
SUMMARY OF EXISTING RAPID SCREENING PROCEDURES

A large number of methods for rapid analysis of seismically hazardous buildings can be found in the literature; however, these are generally abbreviated engineering analyses, requiring a trained engineer and access to the structural drawings. Only a few rapid visual screening methods have been found to exist, and none has had widespread practical application. Some of the available methods have been tested in limited areas for the purpose of refining the survey techniques but never have been applied to an entire community. In many cases the survey method that was chosen depended upon the ultimate use of the data that were gathered—for example, property loss estimation or life-safety estimation versus hazardous building identification. Thus, the different survey formats are in many cases a result of different goals, budgets, and personnel requirements.

This section presents citations and a summary of each RSP identified during the review of the literature, present practice, and community surveys. Each RSP has a brief acronym or other identifier (e.g., NBS 61 refers to the methodology developed at the National Bureau of Standards by Culver et al., 1975; OAKLAND study refers to a survey of buildings in the City of Oakland published in 1984), a bibliographic citation, and typically a one-paragraph summary overview of the methodology or study. The rapid screening procedures have been divided into two groups, surveys and methods, and are presented in reverse chronological order within each of these groups. Surveys are defined as those RSPs that have actually been applied to a real community. Methods are defined as those RSPs that are found in the literature, but as far as could be ascertained have not been applied to any community. Comparisons of certain aspects of the methods are presented in tables in Chapter 4.

SURVEYS

City of Redlands Study. Seismic Strengthening, Final Report and Handbook (1987). Report published by the Department of Economic and Community Development, County of San Bernardino, California. Also M. Green, personal communication.

> This handbook develops an RSP and presents a case study in the City of Redlands, California. The study was sponsored by the County of San Bernardino and the Southern California Earthquake Preparedness Project to identify potentially hazardous unreinforced masonry bearing wall buildings and to encourage voluntary seismic strengthening. The visual survey is designed to be conducted by inspector level personnel, with data being entered on forms (provided herein in Appendix A). Initial survey target areas were chosen based on the density of suspect unreinforced masonry buildings. Design level, building configuration, non-structural hazards, and adjacencies were used to identify the hazardous buildings. The survey resulted in maps showing the distribution and location of hazardous buildings in the city. Buildings were then ranked using a chart of tolerability of failure versus probability of failure for each building. The ranking included occupancy information. In its present

form, the method is limited to URM bearing wall structures and is therefore too limited for an ideal RSP.

San Francisco Study. A Survey of Unreinforced Masonry Buildings in San Francisco (1987). Report by Seismic Investigation & Hazards Survey Advisory Committee, and Department of Public Works. F. Lew, personal communication.

This survey was conducted by the San Francisco Building Department (1985-1986) to identify all unreinforced masonry buildings in the city. An office phase employed Assessor's files, Sanborn maps and Parapet Safety Program files to identify pre-1950 non-wood construction (approx. 6000). Every street in the city was then visually screened by building inspectors to determine and confirm which buildings were unreinforced masonry. The result of the survey is a list of approximately 2100 unreinforced masonry buildings that will be used with a future ordinance specifying mitigation procedures and timetables. Factors such as building configuration, occupancy, age and size were noted, but this information was not used. Costs and level of effort are as follows: two inspectors full time for one year surveyed this city of 700,000 population for a total reported cost of $120,000 (including clerical support).

ABAG. Perkins et al. (1986). Building Stock and Earthquake Losses - The San Francisco Bay Area Example Report by the Association of Bay Area Governments (ABAG), Oakland, California.

This is a survey conducted to estimate the building inventory for nine San Francisco Bay Area counties for estimation of earthquake losses. Specific hazardous buildings were not identified; only estimates of the number and geographic distribution of buildings of each type were provided. Hence, there is no well-defined methodology for identifying specific seismically hazardous buildings. Many of the data were collected from land use maps, interviews with local building officials, Sanborn maps, and previous studies. "Windshield" surveys were conducted by ABAG project staff and a graduate student in architecture to supplement data on building types and to identify seismically suspicious unreinforced masonry buildings in older downtown, commercial, and industrial areas.

Stanford Project. Thurston, H. M., Dong, W., Boissonnade, A. C., Neghabat, F., Gere, J. M., and H. C. Shah (1986). Risk Analysis and Seismic Safety of Existing Buildings. John A. Blume Earthquake Engineering Center, TR-81, Stanford University, Stanford, CA.

This expert-system based method has two steps: (1) Using a computer program, Insight 2 (termed an expert shell), a pre-field screening is performed on the basis of geology, ground motion (MMI), building importance, and vulnerability (furnished from building department and other sources). (2) If the pre-field screening warrants it, an inspection of the building including drawings and building access is performed. A numerical value for risk is assigned using an expert system built from the Deciding Factor shell. (Loosely defined, an expert-system is a computerized data base or "knowledge base" containing logic and rules that process input information to arrive at some conclusion. Ideally its logic is similar to the thought process of a human expert.) Palo Alto was used as a case study to validate the expert system by comparing its risk evaluations with those of experts. Sample data sheets are included herein in Appendix A. The use of an expert system to supplement visually obtained survey data should make this method suitable for a larger target audience; however, in its present form the field survey is too detailed for a rapid visual procedure. In addition, the weighting scheme used to rank building hazard is subjective and not based specifically on damage-related data. This is an extension of earlier work by Miyasato et al. (1986).

Low-Rise Study. Wiggins, J. H., and C. Taylor (1986). Damageability of Low-Rise Construction, Vol. II & IV. Report by NTS Engineering for National Science Foundation, Long Beach, California.

This is an NSF-supported project to develop a methodology to estimate earthquake losses in low-rise buildings. A rating scheme based on a maximum value of 180 points is used. This study is an extension of the method developed for the 1971 Long Beach study. The insurance industry is the primary user of this method. Data gathering, however, is not done by field inspectors. Instead a short questionnaire about relevant aspects of the structure is completed by the building owner and decisions are made from the responses. As such, this is not an RSP.

U.S.-Italy Workshop. Angeletti, P., and V. Petrini (1985). Vulnerability Assessment, Case Studies. US-Italy Workshop on Seismic Hazard and Risk Analysis (Damage Assessment Methodologies), Varenna, Italy, 73-100.

Two methods are presented. The first, a subjective side walk survey, can be performed quickly (12–16 buildings/day per team), and the second is a more in-depth survey with quantitative vulnerability assessments (4–8 buildings/day per team). Both methods were tested on 490 buildings (379 masonry, 111 reinforced concrete) in Forli, Italy, in 1984, using 100 public technicians and 15 earthquake engineering experts and on 293 buildings (279 masonry, 14 reinforced concrete) in Campi Bisenzio. The results are in the form of histograms and maps of vulnerability classes.

Charleston Survey. Survey of Critical Facilities for the City of Charleston, South Carolina (1984-1985). M. Harlan, personal communication.

This study, funded by FEMA, was conducted for the purpose of estimating structural vulnerability and loss of function for the Charleston area in the event of a large earthquake. The study was not used to identify buildings for seismic rehabilitation. Probable Maximum Loss (PML), was used as the measure of damage. (PML was defined by Steinbrugge (1982) as the "expected maximum percentage monetary loss that will not be exceeded for 9 out of 10 buildings.") All critical facilities were evaluated, totaling about 350 buildings. No non-critical facilities were reviewed. Copies of the survey forms and rating forms are included in Appendix A. The advantage of these forms is that they are in a check-off format, thus minimizing omissions. The disadvantage is that they are too long for a rapid visual procedure. This survey was much more detailed than an RSP. Building entrance and plan review were often necessary to determine the PML modifiers needed for Steinbrugge's method. The vulnerability report has not yet been published. Third or fourth year university engineering students performed the survey. Students were given one to two weeks of training before going into the field. Each student reviewed an average of 3 buildings per day. Cost data were not available.

Palo Alto Survey. Survey of Buildings for the City of Palo Alto (1984-85), F. Herman, personal communication.

In 1984-1985, a local jurisdiction (Palo Alto, California) developed an ordinance and a survey method to identify and cite seismically hazardous unreinforced masonry and other specified buildings. The survey focused on three types of structures: (1) unreinforced masonry, (2) pre-1935 construction with more than 100 occupants, and (3) pre-1976 construction with more than 300 occupants. Seismically hazardous buildings were identified, primarily based on age and type of construction, number of occupants, and present condition. A sidewalk survey conducted by civil engineering graduate students under the supervision of a building department official was supplemented with Sanborn maps, building department files, and information from a previous survey conducted in 1936. Hazardous buildings were cited and owners were given one to two years to submit a detailed structural analysis of the building for city review. Examination of the several sample data sheets (included in Appendix A) shows that very little site or structure-specific information was requested in the sidewalk survey. All information about configuration problems, nonstructural hazards, and building dimensions would be included in the remarks area at the discretion of the inspector. This is because the method was essentially pass/fail based on whether a building could be classified into one of the three categories described above.

Oakland Study. Arnold, C. A. and R.K. Eisner (1984). Planning Information for Earthquake Hazard Response and Reduction. Building Systems Development Inc., San Mateo, California.

This is an NSF-sponsored investigation by Building Systems Development and the University of California, Berkeley, of urban planning for seismic risk mitigation, using Oakland as a case study. The procedure was mainly a sidewalk survey of building exteriors following an initial screening using information from Sanborn maps, assessor's files, and building permits. The survey was conducted by graduate students in architecture with guidance from a registered architect. The final product was the identification of "seismically suspicious" buildings, determined mostly on the basis of structural system and configuration factors and, to some extent, occupancy. Some factors, such as non-structural hazards, were noted, but it is not clear that they were used in identifying the seismically suspicious buildings. The report does not specify how the collected data were combined to determine the hazard of a building and thus the method requires a great deal of technical judgment. An example of the data collection sheet used in the sidewalk survey is included in Appendix A. Although building types and occupancy classes are well defined, other information is loosely defined, possibly leading to a lack of consistency among different data collectors. The level of effort expended involved 2 graduate students in architecture, a total of approximately 350 hours for 2500 buildings, and an approximate cost of $20,000.

Multihazard Survey. Reitherman, R., Cuzner, G., and R. W. Hubenette (1984). Multihazard Survey Procedures. Report by Scientific Service, Inc., Redwood City, California, for FEMA. (R. Hubenette, personal communication).

This method, developed for FEMA and

adopted in FEMA technical report TR-84, is designed to apply to essential facilities necessary for disaster operations. The method identifies and quantifies, on a scale of 1 to 5, a building's vulnerabiliy to radiation, fire, earthquake, high wind, tornado, hurricane, and flood hazards. The vulnerability is determined from a combination of the resistance of the construction and the exposure of the building to the particular hazard, but this calculation is not done by the surveyor. All data are processed by computer at the national level (FEMA). The method has been adopted and implemented since 1985 in many states, including California, Florida, North Carolina and Arizona. However, the priority for the multi-hazard surveys is civil defense related, and in many cases the earthquake portion of the survey is not performed. All survey data are collected on a standardized form (included in Appendix A) and are entered in a national database. The data collection form is organized to facilitate the computerized data processing, but it is difficult to follow. Rather than a checkoff format, the form requires the use of numerical codes that are not easily memorized. One of the promising and unique features of this method is that inference rules are provided for cases when visual inspections, drawings, and other supplemental information are not adequate to positively answer survey questions. The method is more detailed than an RSP, as building entrance is necessary and sometimes plans are reviewed. The survey can take from one hour to three days per building. Survey personnel need a minimum of two years undergraduate technical background. Cost information was not available.

New Madrid Study. An Assessment of Damage and Casualties for Six Cities in the Central United States Resulting from Two Earthquakes, M=7.6 and M=8.6, in the New Madrid Seismic Zone (1983). Report by Allen & Hoshall, Inc., Memphis, Tennessee, for FEMA.

This study, also known as the Six Cities Study, assesses damage due to earthquakes on the New Madrid fault zone. An extensive inventory of buildings was supplied by FEMA for the six project cities. These data were checked and in some cases supplemented by visits to the sites by a structural engineer and an engineering technician. In other cases, the data were verified by telephone contact with facility managers. The inventory was limited to a few representative structures of well-defined classes such as hospitals, critical structures, transportation systems, public utilities, and schools, and was primarily to assess the type of construction for each of the classes. Three different survey forms were available depending on the class of the structure and information required (see Appendix A). This is not a rapid visual screening procedure, but a sampling procedure to infer the properties of the larger building inventory for use with fragility curves to estimate damage. Cost information was not available.

OSA Hospital Survey. Earthquake Survivability Potential for General Acute Care Hospitals in the Southern California Uplift Area (1982). Report by Office of the State Architect for Office of Statewide Health Planning and Development, California. J. Meehan, personal communication.

This inventory and evaluation of hospitals in the Palmdale Bulge area were done by structural engineers from the Office of the State Architect. Hospitals were classified into six "survivability index" categories from A (low risk) to F (high risk) based on the date of construction and structural information. The criteria used in this survey require extensive engineering judgment and are specific to hospitals as they are based on adherence to Titles 17 and 24 of the California Administrative Code. Data were gathered by extensive interior and exterior visual inspections along with an in-depth review of construction drawings when possible. Level of effort was probably one to two engineer-days per hospital, depending on the complexity. This was not a rapid procedure, but rather a detailed inventory of hospital resources, such as beds and rooms, as well as anchorage of equipment and availability of emergency services.

Los Angeles Study. Survey of Unreinforced Masonry Bearing Wall Buildings (1978-1979) for the City of Los Angeles. E. Schwartz, personal communication.

This study in the City of Los Angeles was performed by city building inspectors during 1978-1979 for the purpose of identifying bearing wall unreinforced masonry buildings, but not infill or other types of URM. Preliminary identification of pre-1934 URM was performed using assessor's files, Sanborn maps, and records from a previous parapet stabilization program, resulting in identifying about 20,000 potentially hazardous buildings. A block-by-block visual survey of building exteriors (and interiors when possible) reduced this to a final count of about 8,000 hazardous buildings. Although configuration and state of repair were noted, the primary criterion used to identify the hazardous buildings was the existence of unreinforced masonry bearing walls. An average of 40 minutes was spent at each building. After the data were collected, hazardous buildings were placed in one of four classes: (1) essential buildings, which were mostly state- or city-owned; (2) high-risk buildings, with more than 100 occupants and/or few interior walls; (3) medium-risk buildings, defined as having 20 to 100 occupants and/or many interior partitions; and (4) low-risk buildings, those buildings with less than 20 occupants. These categories were used to prioritize the mitigation procedures. The level of effort expended involved 6 inspectors, 1 senior inspector, 1 structural engineer, 2 clericals, all for 2 years, at a cost of approximately $400,000.

University of California Study. McClure, F. E. (1984). "Development and Implementation of the University of California Seismic Safety Policy." Proceedings, Eighth World Conference on Earthquake Engineering, San Francisco, 859-865. F. McClure and L. Wyllie, personal communication.

In response to the 1975 seismic safety policy implemented by the University of California, a survey of buildings with area greater than 4,000 sq ft and with human occupancy was conducted by experienced structural engineers (Degenkolb Associates were consultants on this project). Based on structural, non-structural and life-safety judgments, a seismic rating of good, fair, poor, or very poor was assigned by observations of building exteriors and a review of design drawings and previous engineering reports. Two to four days were spent on each of 9 campuses, for a total review of 44 million sq ft, of which 21% rated poor or very poor. The effort was split between reviewing drawings and on-site inspection. There were no formal criteria in this study, as decisions were made on a building by building basis. A considerable amount of judgment and engineering experience was required to perform this survey.

Santa Rosa Study. Identification of Seismically Hazardous Buildings in Santa Rosa, 1971-present. W. E. Myers. personal communication. Also, Myers, W. E. (1981). "Identification and Abatement of Earthquake Hazards in Existing Buildings in the City of Santa Rosa." Proceedings, 50th Annual SEAOC Convention, Coronado, CA, 55-66.

This study arose from an ordinance adopted by the Santa Rosa City Council in 1971 to review all buildings constructed before December 31, 1957 (one and two-story wood frame, single family dwellings were exempt from the review process). A preliminary review is performed by a city official (experienced structural engineer) to determine if further review is necessary, based on whether the building complies with the 1955 UBC. Any further review is the responsibility of the building owner and must be prepared by a structural or civil engineer. The initial screening consists of a half day (on average) detailed site inspection involving entry into the building, including the basement, attic, and other portions of the building, noting such features as wall ties, openings, and diaphragms. Fire as well as earthquake-related hazards are usually identified. Data are collected using a handheld tape recorder, and later transcribed. Where possible, plans are examined, although in many cases they are unavailable. In a few cases rough calculations are performed. Subsequently a report is written (2 to 20 pages depending on the complexity of the structure) and submitted to the owner with a timeline for mitigation. The established priority of review was based on the number of occupants, buildings with the most occupants being reviewed first. Reviews began in 1972 on churches and other buildings with assembly occupancy greater than 100 persons, and in 1987 the city was reviewing buildings with smaller occupancy such as office buildings and retail stores. Between 1972 and 1987, approximately 400 buildings were initially reviewed (out of approximately 600 in the city) with about 90 percent requiring further review. Due to the detailed nature of the visual inspection and the level of engineering expertise required, this does not fulfill the definition of an RSP. The level of effort expended was: 1 full-time engineer employed by the city for 15 years, and a cost of approximately $500 per building.

Long Beach Study. Wiggins, J. H., and D. F. Moran (1971). Earthquake Safety in the City of Long Beach Based on the Concept of Balanced Risk. Report by J. H. Wiggins Co., Redondo Beach, California. Also E. O'Connor, personal communication.

This study was developed as part of a model ordinance (Subdivision 80) for the City of Long Beach. It was a significant advancement in the techniques of rapid identification of seismically hazardous buildings. In the original methodology, five factors were scored and combined to form a hazard index: (a) framing system/walls, (b) diaphragm/bracing, (c) partitions, (d) special hazards, and (e) physical condition. A score of 0–50 indicated rehabilitation was not required; 51–100 indicated some strengthening was required; and 101–180 indicated a serious life hazard existed. This widely known method was not directly employed by Long Beach but was modified in the ordinance to score the following five structural resistance factors for unreinforced masonry: (a) wall stability, (b) wall anchorage, (c) diaphragm capacity, (d) shear connection capacity, and (e) shear or moment resisting element capacity. Occupancy, importance and occupancy potential factors were also included. A survey of 928 pre-1934, type 1, 2 or 3 buildings was conducted by city building inspectors over several years. Deadlines for hazard mitigation depend on the ranking provided by the hazard index.

METHODS

Seismic Design Guidelines for Upgrading Existing Buildings (A Supplement to "Seismic Design Guidelines for Buildings") (1986). Dept. of the Army.

> This is a methodology developed for the Army that contains both a rapid visual component and a detailed structural analysis. The result of the visual survey is a list of buildings that should be further reviewed. The first step is to eliminate buildings from the survey inventory using eight prescribed criteria. The remaining buildings are then classified as (1) essential, (2) high risk or (3) all others. All available design criteria such as drawings, calculations, and specifications are compiled and pertinent information is transferred to the screening form (Appendix A). A field survey is then performed, allocating 10 to 30 minutes per building. Buildings are eliminated from the list if it would not be feasible or cost effective to upgrade them, or if they are identical to other structures that will be reviewed.

ATC-14, (ATC, 1987). Evaluating the Seismic Resistance of Existing Buildings. Applied Technology Council, Redwood City, California.

> Although this extensive methodology contains no rapid visual screening aspect, it is included in this review because Section 4.2.2 and Appendix C of ATC-14 contain checklists of features that, if elaborated, could form the basis for an RSP. Moreover, buildings identified by the ATC-21 methodology as seismically hazardous should be reviewed in detail with the methodology presented in the ATC-22 Handbook (in preparation), which is based on the ATC-14 methodology.

A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. U.S. Department of Housing & Urban Development, 3 volumes. Pinkham, C. W., and G. C. Hart (1977).

> This method is based on NBS 61 (described below); however in this case only Masonry B (UBC 73, sections 2414, 2415 and 2418) and Masonry A (all other concrete or brick masonry) are targeted. This is essentially a rapid analysis procedure with a preliminary visual screening component. The data collection forms are the same as those for NBS 61. However, the criteria for preliminary screening are not well defined and therefore require a good deal of judgment.

NBS 61. Culver, C. G, Lew, H. S., Hart, G. C., and C. W. Pinkham (1975). Natural Hazards Evaluation of Existing Buildings, BSS 61, National Bureau of Standards, Washington, D.C.

> This is an extensively developed methodology, designed for building officials and engineers, to evaluate existing buildings for major natural hazards: earthquake, high wind, tornado, and hurricane. Evaluation of existing buildings is performed in three levels, the first of which is a simple visual procedure, providing input to several simple equations that result in a Capacity Rating (CR). This method has been widely referenced but not directly or explicitly applied to any region, as far as could be determined. Data collection forms and field evaluation forms are

included in Appendix A. It can be seen that the data collection forms are quite extensive and assume that the inspector will have access to the interior of the building and to soils and geologic reports; thus, this is not a true sidewalk survey. Brèsler et al. (1975) point out that the weights employed and the algorithms or equations for determining the capacity ratio (see field evaluation forms) are arbitrary and gave misleading results for a trial building they examined.

Not included in this list are earthquake loss estimation studies such as those prepared by the federal government for the Los Angeles area (NOAA, 1973), Salt Lake City area (USGS, 1976), San Francisco Bay area (NOAA, 1972), and Puget Sound, Washington, area (USGS, 1975).

4
EVALUATION OF EXISTING RAPID SCREENING PROCEDURES

This section evaluates the previously discussed RSPs and studies according to several broad categories. Because each method/study reviewed was unique in some aspects, the following broad categories within which to compare and comment on the detailed aspects were defined:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

These five broad categories were selected as being of greatest interest to one or several segments of the target audience. To facilitate comparison, a tabular format has been used. Within each category specific items were noted, as were whether a specific RSP method or study addressed this issue, employed this data item, or simply noted this item. Where an entry is blank, no information was available.

Organizational—Refers to the general aspects of an RSP method or study that would be of interest to a person or organization implementing and managing a survey of a community. These include items such as the size of the survey defined by number of buildings, population and/or area; the types of buildings that were targeted; and whether graphic methods (sketches or photos) were used to record data.

Structural—Refers to structure-specific data items that would be of most interest and use to a structural engineer (e.g., age, structural material).

Configuration —Includes items such as whether an RSP method or study specifically noted soft stories or irregular building configuration. This would be of interest and use to architects and engineers.

Site and Non-Structural—Includes items related to the site (e.g., soil conditions, potential for pounding), and to the non-structural aspects of a building that may either pose a hazard (e.g., parapets) or may affect structural behavior (e.g., infill walls).

Personnel—Addresses two aspects regarding the qualifications of the personnel who would employ the specific RSP or study being evaluated: (1) What were the backgrounds or qualifications of the personnel who conducted the study or for whom the method was intended? (2) Could the method be applied by each or any segment of the target audience?

After reviewing all the existing surveys and available data, it becomes clear that there is currently relatively little statistical information relating damage to all types of structures under different levels of earthquake loading. Although general statements about the behavior of buildings in earthquakes can be made, it is difficult to quantify the damage. Even general statements about vulnerability based on building type are subject to question because so many other aspects such as configuration, connection detailing or local site conditions can contribute to poor structural performance. Reitherman (1985) noted that architectural configuration can be quite different from structural configuration and thus can be very misleading without access to structural drawings. Structural detailing, which can be so critical to good performance, is difficult to "score" from purely visual inspections. For these reasons, the results of an RSP cannot be regarded as definitive, and structural adequacy or lack thereof can only be determined on the basis of detailed examination by a registered professional engineer.

4.1 Organizational Aspects

Table 1 presents the evaluation of the organizational aspects of the various methods/studies. Specific items considered are discussed below.

Building Groups Targeted: Most methods or studies begin by eliminating some building types as non-hazardous (e.g., wood-frame construction), and limiting themselves to simply identifying that building type considered "most hazardous" (e.g., URM), or they have a well-defined list of structural types in their evaluation methodology. This report identifies those building types that were addressed.

Survey Area: In the case of studies where buildings in a community were actually screened, some measure of the size of the project, such as number of buildings, area, population, or other measure, is indicated.

Number of Hazardous Buildings Identified: As above, where available, the number of hazardous buildings actually identified for the particular study is indicated.

Method: A brief description of whether the method/study (i) simply employed a pass/fail measure (e.g., is or is not URM), or (ii) employed subjective measures and techniques (e.g., has a soft story, is irregular) without quantifying these items, or (iii) employed numerical scoring schemes and algorithms for combining information to arrive at a quantified measure (e.g., tension-only bracing or long-span diaphragms are given weights and these are "scored" in some fashion).

Supplemental Information Employed: Was non-visual off-site information employed, such as from building department, assessor files, Sanborn maps, or previous studies?

Explicit Earthquake Definition: Was the "earthquake loading" explicitly defined? Many times a method/study determined that buildings were seismically hazardous without clearly defining what ground motions the building was being compared against. Admittedly, for a specific jurisdiction this might be implicitly clear (e.g., a repeat of the 1906 event for San Francisco), but this aspect would need clear definition for any general RSP.

Sketch or Photo: Sketches or photos as an integral part of the data recording are invaluable for later reference. Requiring sketches assures that the survey personnel methodically observe the building.

4.2 Structural Aspects

Table 2 presents an evaluation of the methods/studies for the structural aspects. Specific items considered are discussed below.

Age/Design Level/Building Practice: Building age is usually an explicit indicator of the design level or the code under which the building was designed, and the building practices prevalent at the time of construction.

State of Repair: Maintenance and general conditions are important aspects of structural adequacy since corrosion and deterioration decreases structural capacity.

Occupancy Factor Definition: Occupancy is not an explicit factor in structural adequacy, but is important in setting priorities.

Material Groups: Broad structural material groupings can be noted in a variety of ways, and are a basic measure of seismic capacity.

Number of Stories/Dimensions: Number of stories and/or the plan or other dimensions are a broad indicator of structural dynamic properties, as well as of value.

Symmetrical Lateral Force Resisting System: The degree of symmetry of the lateral force resisting systems (LFRS) is an important clue as to adequacy of load path. If this was an item of interest to the survey team, what guidelines were they given for identifying the LFRS? If noted, how was the degree of symmetry employed?

Member Proportions: Were these noted in any way? Relatively thin member proportions are a general indication of potential problems in connections and/or member stability and, for concrete members, usually indicate non-ductile detailing.

Sudden Changes in Member Dimensions: Drastic changes in column dimensions can sometimes be observed through windows, and would indicate upper story "softness." Were these noted?

Tension-only Bracing: Was this relatively non-ductile behaving system identified as an item to note if observed?

Connections Noted: Was any attention paid to connections, as for example whether special wall/diaphragm ties were present in bearing-wall systems (e.g., tilt-up, URM)?

Previous Earthquake Damage: In areas where previous earthquakes might have weakened a building, was any attempt made to look for indications of this damage?

Renovated: Was there any indication that the building had been renovated, either with regard to architectural (thus obscuring the age) or structural details?

4.3 Configuration Aspects

Table 3 presents an evaluation of the methods/studies for the configuration aspects. Specific items considered are discussed below.

Soft Story: Abrupt changes and/or decrease in stiffness in lower stories of a building lead to large story drifts that cannot be accommodated. Was this consideration incorporated into the determination of seismic hazard, or was it noted by survey personnel but not used? Similarly, were plan irregularity, vertical irregularity, excessive openings and aspect ratio of the building or its components (vertical or horizontal) considered?

Corner Building: Buildings on corners typically have potential torsional problems due to adjacency of two relatively infilled back walls, and two relatively open street facades.

4.4 Site and Non-structural Aspects

Table 4 presents an evaluation of the methods/studies for the site and non-structural aspects. Specific items considered are discussed below.

Site-Related: So-called "adjacency" problems of pounding and/or the potential for a neighboring building to collapse onto the subject building are important structural hazards. These are two aspects that can be easily observed from the street and that the 1985 Mexico City experience again emphasized as critical. These were placed under site-related rather than structural or configuration because they involve aspects that are more related to the site and adjacent buildings than to the subject building per se.

Soil conditions or potential for seismic hazards other than shaking, such as landslide or liquefaction, are also very significant factors related as much to the site as to the structure. Admittedly, these non-shaking hazards may more easily be defined on the basis of reference maps than in the field, but in the methods reviewed were these given any consideration at all? Were soft soil/tall building or stiff site/stiff building correlations attempted as a crude measure of resonance/long period potential?

Non-Structural: Were major infill walls and/or interior partitions and their potential effects on structural behavior, especially in light buildings, noted? Were the special and relatively obvious seismic hazards of cornices, parapets, chimneys and other overhanging projections noted?

4.5 Personnel Aspects

Table 5 presents an evaluation of the methods/studies for the personnel aspects. For most projects, cost information was difficult to obtain and was usually based on criteria that are not easily compared. Some data provided included clerical and report production costs, others only the costs of survey personnel. This report provides personnel time per building reported for a particular RSP. By multiplying by labor cost, and including other expenses such as transportation and report production costs, the reader can estimate what a particular RSP would cost if applied to a particular community. Whether or not the particular RSP is appropriate for use by each segment of our target audience is indicated (by Y or N).

4.6 State of the Practice

Information provided by about a dozen practicing structural engineering firms, mostly in California, indicates that no rapid visual screening procedure is currently being used by practitioners. Typically, structural engineers have used visual screening procedures as a preliminary phase of a more detailed analysis. However, because most of the procedures involved entrance into buildings and detailed inventories of structural elements and non-structural elements, these procedures do not fit the definition of "rapid visual screening" utilized herein.

"Subjective judgment" is the type of criteria used most extensively to classify seismically hazardous buildings; in only a few cases have quantitative criteria been developed. However, in most cases, studies have been for planning purposes, and engineers have tried to include some qualitative indicator of the degree of hazard of the building to assist in setting priorities for mitigation procedures. In general, the surveys have been performed by experienced engineers or by entry-level engineers accompanied by a more experienced engineer. Most often, junior personnel have been given brief training as to what to look for and a checklist or data collection form, usually without detailed written guidelines. In some cases, a trial run through a building with the data collection forms was performed under the supervision of an experienced engineer. Usually there were no structured guidelines for identifying a building as one structural type or another, nor was there any consistent way to incorporate the uncertainty in the judgments that were made. Consequently, the variability in backgrounds and experience of the personnel and the lack of detailed guidelines can result in widely differing interpretations of the criteria for identifying hazardous buildings and hence produce inconsistent results.

4.7 Conclusions

The foregoing review indicates that no currently available RSP method or study addresses all of the major aspects fundamental to seismic hazard, and further that no really satisfactory RSP method or procedure exists. Most omit many of the described aspects, and/or are very subjective in their treatment of the data recorded. In many cases, too much reliance is placed on the experience of the survey personnel, with little attention paid to consistency among different personnel. Further, although the personnel may have been given some coaching or training in what to look for, this was usually unsystematic and omitted major aspects.

Most of the rapid visual screening procedures that were reviewed were developed for a particular municipality and thus were applied in only one geographic region. None addresses the issues of regional differences in construction practices and building code regulations. The multihazard study (Reitherman et al., 1984), NBS 61 (Culver et al., 1975) and the Navy Rapid Seismic Analysis Procedure are designed for nationwide application, but these procedures do not specifically discuss differences in building performance that might result from regional engineering and construction practices. In addition, they involve entrance into the building or calculations and thus are too detailed for an RSP.

From the studies that were reviewed and from experience with earthquake-related damage, a set of attributes of a satisfactory RSP method was developed:

1. The earthquake loading against which the building's capacity is being judged should be explicitly defined, preferably in physically based units (e.g., acceleration). The anticipated earthquake loading is defined in several of the studies such as NBS 61, the Stanford Project, the University of California Study, the OSA Hospital Survey, the New Madrid Study and the Multihazard Survey; however, non-physical units such as UBC zone or MMI are used. Only in Wiggins and Moran (1971), and Wiggins and Taylor (1986) is the use of maximum expected bedrock acceleration discussed. Because the decision of what ground motion a building should satisfactorily withstand involves not only geotechnical and seismological issues but also difficult questions of acceptable risk, the "acceptable earthquake" may often be decided in an iterative fashion. Thus, sufficient building-specific data should be clearly recorded to permit later calculations for the purposes of re-screening, given a different "earthquake loading."

2. As much as possible, supplemental information compiled from building department and assessor's files, Sanborn maps and other sources should be collated and taken into the field in a usable format, such as computer listings or peel-off labels that can be affixed to the survey form, for verification as well as aiding the field personnel. Most of the methods that were reviewed use other sources of information to supplement the visually obtained data.

3. An RSP should have the capability to survey and identify hazardous buildings of all types. In some cases, jurisdictions may wish to use the RSP in a limited form for certain "high hazard" target buildings or areas. However, all building groups should receive at least an initial limited-sample-area test screening to verify assumptions of which building type is the most hazardous within the local building stock. If these assumptions are verified, then selected building groups/areas may be targeted for reasons of economy. However, the situation of having identified all URM buildings, and having no idea of the seismic hazards in the older non-ductile reinforced concrete building group, for example, or the older unbolted house-over-garage (HOG) building group, should be avoided.

4. A quantitative approach, as exemplified in the Long Beach study (Wiggins and Moran, 1971) or NBS61 (Culver et al., 1975), appears preferable, as it not only permits pass/fail decisions, but also allows prioritization within the "failed" category. However, the quantitative "scoring" should not be arbitrary but rather should be rationally based, as far as possible.

5. Sketches should be an integral part of the data recording to assure that the survey personnel methodically observe the building. Sketches and photos are invaluable for later reference, and ideally both should be part of the field data

recording because they are complementary. Several of the reviewed methods omitted a sketch or photo.

6. Age should be explicitly recorded. Although often unavailable, age can be estimated, usually to within a decade or two, on the basis of architectural style, and thus can indicate whether a building is pre or post a specific "benchmark" year in the development of that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building is pre-1948, it is likely to be unbolted. Similarly, unreinforced masonry was not permitted after the adoption of the 1948 building code. Thus, in a survey of hazardous buildings in San Francisco, only pre-1950 buildings were considered. These benchmark years differ by jurisdiction, but are usually locally known or can be determined and should be included in training material for survey personnel.

7. State of repair should be explicitly noted, as it forces the survey personnel to look for cracks, rot, corrosion and lack of maintenance. Although the state of repair was noted in many of the methods reviewed, it was not formally used in identifying the seismically hazardous buildings.

8. Occupancy (use) and number of occupants should be noted, using standardized occupancy categories. In the Los Angeles and Long Beach studies, occupancy was used to prioritize buildings for hazard abatement.

9. Specific observable details of structural members, structural hazards and foundation and site conditions should be itemized in a check-off format, to avoid omission.

10. Configuration issues should similarly be considered, but their contribution to seismic hazard must be quantified, at least on a weighting basis. Although some of the methods, such as NBS 61, have addressed configuration problems the scoring systems are subjective and are not based on actual damage-related data.

11. Site aspects of pounding, corner building and adjacencies, and non-structural aspects, need to be similarly noted. Few of the methods have used pounding, corner buildings, or adjacencies as criteria for identifying hazardous buildings, although these problems were noted. Several studies (e.g., City of Redlands, Multihazard Survey, NBS 61) consider non-structural hazards explicitly as part of their criteria.

12. Personnel should have adequate background and training to understand the earthquake behavior of buildings because many of the data they will be called upon to record will involve subjective decisions. In addition, the survey should be accompanied by detailed guidelines as to what to look for and how to interpret and indicate uncertain data to avoid inconsistencies in the data collection. The guidelines presented in the Multihazard Survey are useful examples.

13. Data recording should be complete and systematic. A field remote-entry electronic format (i.e., a "laptop" computer) should be considered, although for economic reasons a clipboard has many advantages.

14. Because information is often lacking, uncertainty considerations must be incorporated into the methodology, although it can be relatively "invisible." For example, building type may be

indicated as (circle as appropriate):

RCMRF* :	definite	likely	possible	unlikely
RCSW:	definite	likely	possible	unlikely
URM:	definite	likely	possible	unlikely

with weights assigned to each, on the basis of their "contribution" to seismic hazard. If it is likely that the building is an RCSW but possible that it is a URM, then the weighting would result in a higher seismic hazard than if the survey personnel were called upon to provide only one typing. The weighting and arithmetic do not need to be performed in the field, although it may be advantageous to have the weighting known to the field personnel.

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*RCMRF: Reinforced concrete moment-resisting frame
RCSW: Reinforced concrete shear wall
URM: Unreinforced masonry

Table 1
ORGANIZATIONAL ASPECTS

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Bearing wall URM	Test survey approximately 200 buildings	Appoximately 160 buildings	Quantitative	Aerial photo Sanborn maps	N	Y
SAN FRANCISO/ Frank Lew	URM pre-1950 construction	Entire city, population 700,000	2100 from initial 6000	Pass/Fail	Assessors' files, Sanborn maps, Parapet Safety Program files, owner feedback	N	N
ABAG/ J. Perkins et al. (1986)	WF, URM, RM, LM, TU, MH	6,000 square miles, population 5.5 million	4700-5700	Subjective	Sanborn maps, Land use maps, interviews with local building office, previous studies	N	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	All 27 defined classes	Phase I Entire city population 50,000	Phase I 4 sub-areas of city identified as most hazardous	Subjective and Quantitative	Palo Alto Comprehensive Plan Building Department input	MMI	Y, sketch
LOW-RISE/ Wiggins and Taylor (1986)	low rise	N/A	N/A	Quantitative	N	Maximum expected bedrock acceleration	Y
PALO ALTO/ F. Herman	URM, pre-1976, pre-1936, TU	2000 focus on older commercial	325	Pass/Fail	Sanborn maps building permits, previous study, owners	N	N

Table 1
(continued)

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
OAKLAND/ Arnold, Eisner (1980, 1984)	URM, WF ND-RC	Approximately 2000, Oakland Central Business District	377 approximately	Subjective, no clear definition of seismically suspicious	Y Sanborn maps, building permit, previous study, assessors' files	N	Photo, building plan, sketch
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Essential facilities, definition left to local jurisidiction All types	About 10,000 buildings since 1975	Unknown	Quantitative	Maps, construction drawings	UBC zone	Y
NEW MADRID/ Allen & Hoshall (1983)	All	Six couties population 1 million, approximately 2,400 buildings	N/A	Subjective, damage states	FEMA data	Y M = 7.6 & M = 8.6 MMI used for damage estimate	N
OSA HOSPITAL/ (1982)	Hospitals, all types of construction	1077	100 in classes E & F "low survive index"	Subjective	Building plans	UBC zone	Unknown
LOS ANGELES/ (1978-79)	URM	Entire city population 3 million, 490 square miles	8,000 approximately	Pass/Fail	Y Sanborn maps assessors' files, previous studies	Not explicit (large Ep.)	2 photos per building, sketch

Table 1
(continued)

PROCEDURE/ Source	Building Groups Targeted	Survey Area (Size, number of buildings, population)	Number of Hazardous Buildings Identified	Method: Pass/Fail, Subjective, Quantitative?	Supplemental Information Employed?	Explicit Earthquake Definition	Sketch or Photo?
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Area greater than 4,000 square feet, human occupancy	44,000 square feet, approximately 800 buildings	9,000 square feet of Poor or Very Poor	Subjective	Previous studies, design drawings	MMI > IX	Y
SANTA ROSA/ Myers (1981)	All types built before 1958	About 400 buildings since 1972	About 90% for further review	Subjective	Plans	N	Photos and sketches
LONG BEACH/ Wiggins and Moran (1971)	Pre-1934 type 1, 2, 3	Entire city, population 500,000	938	Quantitative	Y Sanborn	N for LB study Y for Wiggins method (maximum expected bedrock acceleration)	Y
NBS 61/ Culver et al. (1975)	SB, DF, SW, CSF, RF, CSW, MSW, WF, 11 building frame types	N/A	N/A	Subjective and Quantitative (Capacity Ratio Rating) Structure Structure rating vs. MMI's	Suggest use of original drawings or soil reports, Sanborn maps	UBC zone, MMI levels > V	Building elevations and site plan with adjacencies, Photo suggested

Table 2
STRUCTURAL ASPECTS

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Proportions	Sudden Changes in Member Dimensions	Tension-only Bracing	Connections	Previous Earthquake Damage	Renovated
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Y	Y	Y	URM	Y	N	N	N	N	Y	N	Y
SAN FRANCISCO/ Frank Lew	Y	N	N	URM	Noted, from assessor file	N	N	N	N	N	N	N
ABAG/ J. Perkins et al. (1986)	N	N	Y noted for some	Concrete Steel Wood Masonry	Y	N	N	N	N	N	N	If available
STANFORD PROJECT/ JABEEC TR 81, Thurston et al (1986)	Y	Y	Y essential facility or large number of occupants, residential, commercial or industrial	Steel Concerete Masonry Wood	Y noted number and dimensions	Y	N	Y	Y	Y	Y	Y
LOW-RISE/ Wiggins and Taylor (1986)	Noted, implicit in some of rating criteria	Y	Noted	Concrete Steel Wood Masonry	Y	Y	N	N	Not explicit, noted inadequate or in-complete bracing	Y	Y noted unrepaired earthquake damage	N

Table 2
(continued)

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Propor-tions	Sudden Changes in Member Dimensions	Tension-only Bracing	Connections	Previous Earthquake Damage	Renovated
PALO ALTO/ F. Herman	Y	Noted but not formally employed	Y (number persons)	URM, TU	Noted but not formally employed	N	N	N	N	N	N	N
OAKLAND/ Lagorio, Arnold Eisner (BSD, 1984)	Y	Noted but not formally employed	Noted importance of structure 17 use codes	URM, TU ND-RC, mixed	Noted	N	N	Noted	N	N	N	Noted
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Y	Y	Noted use	Many classes	Y	Strong beam, weak columns	N	N	Y	Roof/wall and anchor bolts	N	Y
NEW MADRID/ Allan & Hoshall (1983)	Y	N	Y	Steel Concrete Masonry Wood	Y	N	N	N	N	N	N	N
OSA HOSPITAL/ (1982)	Y Building code jurisdiction	Y	Y Noted building use, Not included in ranking	Concrete Steel Masonry Wood	Y	Y	N	Y	Y	N accessed from plans	Not sure	Y
LOS ANGELES/ (1978-1979)	Y	Noted cracks & mortar condition	Y Table 33A UBC	URM	Y	Noted	N	N	Noted from parapet program	N	Noted	Noted from parapet program

Table 2
(continued)

PROCEDURE/ Source	Age/Design Level/ Building Practice	State of Repair	Occupancy Factor Definition	Material Groups	Number of Stories/ Dimensions	Symmetrical LFRS	Member Propor- tiosn	Sudden Changes in Member Dimensions	Tension- only Bracing	Connections	Previous Earthquake Damage	Renovated
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Y	Noted but not significant in ranking	N	Concrete Steel Wood Masonry	Number stories dimensions from plans	Y	Y	Y	Y, not much found	Sometimes	At a few campuses	Y
SANTA ROSA/ Myers (1981)	Y	Y	Noted but not included in decision	No formal groups defined All types examined	Y	Y	N	Y	Y	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	N	Y	N, noted but not formally employed	RC, S, W, URM, RM	Y	Y	N	N	N	N	Y i.e., state of repair noted	N
NBS 61/ Culver et al. (1975)	Y noted but not formally employed employed	Y evidence of past damage repair noted	N noted but not formally employed	Concrete Masonry Steel Wood	Noted	Y	N	N	N	Y, if possible	N	Date noted

Table 3
CONFIGURATION ASPECTS

PROCEDURE/ Source	Soft Story	Plan Irregularity	Vertical Irregularity and Variation in Stiffness	Excessive Openings	Aspect (Vertical or Horizontal)	Corner Building
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	N	N	N	N	N	Y can be inferred from site location sketch
SAN FRANCISCO/ Frank Lew	Noted	Noted	Noted	N	N	N
ABAG/ J. Perkins et. al. (1986)	Y	Y	Y	Y	Y	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Y	Y	Y	Noted	Y	N
LOW-RISE/ Wiggins and Taylor (1986)	Y	Y	Y	Y	Y	N
PALO ALTO/ F. Herman	N	N	N	N	N	N
OAKLAND/ Arnold, Eisner (1984)	Y	Y	Y	Y	N	N

Table 3
(continued)

PROCEDURE/ Source	Soft Story	Plan Irregularity	Vertical Irregularity and Variation in Stiffness	Excessive Openings	Aspect (Vertical or Horizontal)	Corner Building
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	Y	Y	Y	Y large door width open side	N	N
NEW MADRID/ Allen & Hoshall (1983)	N	N	N	N	N	N
OSA HOSPITAL/ (1982)	Y	Y	Y	Y percent openings noted	Y	N
LOS ANGELES/ (1978-79)	Not specific percent openings	Y	Y	Y percent openings noted	N	N
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Y	Y	Y	Y	Y	N/A
SANTA ROSA/ Myers (1981)	Y	Y	Y	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	N	Y	Y	Y	Y	N
NBS 61/ Culver et al. (1975)	Y, noted	N	Y, Noted	Y, noted	N	Street sides noted

Table 4
SITE AND NON-STRUCTURAL ASPECTS

PROCEDURE/ Source	SITE RELATED: Pounding	SITE RELATED: Neighboring Building Collapse	SITE RELATED: Soil Conditions	SITE RELATED: Potential for Other Geohazards	NON-STRUCTURAL: Infill Walls	NON-STRUCTURAL: Interior Partitions	NON-STRUCTURAL: Cornices, Overhang Parapets, Chimneys
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Noted abutting buildings	Noted abutting buildings	N	N	N	Noted type	Y cornice parapet chimney signs ornament
SAN FRANCISCO/ Frank Lew	N	N	N	N	N	N	Noted
ABAG/ J. Perkins et al. (1986)	N	N	Not explicit, used map overlay	Not explicit, used map overlay	N	N	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Y	Y, noted	Y, noted	Y	Y	Y	Y
LOW-RISE/ Wiggins and Taylor (1986)	N	Y Neighboring overhang collapse	Y	N	Y	Y	Y
PALO ALTO/ F. Herman	N	N	N	N	N	N	N

Table 4
(continued)

	SITE RELATED				NON-STRUCTURAL		
PROCEDURE/ Source	Pounding	Neighboring Building Collapse	Soil Conditions	Potential for Other Geohazards	Infill Walls	Interior Partitions	Cornices, Overhang Parapets, Chimneys
OAKLAND/ Arnold, Eisner (1980, 1984)	N	N	N	N	Noted	N	Noted
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	N	N	Y Soft or hard	Landslide liquefaction Settlement Surface faulting	Y noted	N	Braced or unbraced or not present
NEW MADRID/ Allen & Hoshall (1983)	N	N	Y	Liquefaction	N	N	Y
OSA HOSPITAL/ (1982)	Noted distance to nearest building	Noted distance to nearest building	N	Liquefaction Landslide Alquist-Priolo seismic zone	N	Y noted URM partitions	N
LOS ANGELES/ (1978-79)	N	N	N	N	N	Y	Y, also from previous parapet program
UNIVERSITY OF CALIFORNIA/ McClure (1984)	Not a problem	N	N	Y Surface faulting in a few locations	N	Y	Y, noted but not significant in ranking

Table 4
(continued)

	SITE RELATED				NON-STRUCTURAL		
PROCEDURE/ Source	Pounding	Neighboring Building Collapse	Soil Conditions	Potential for Other Geohazards	Infill Walls	Interior Partitions	Cornices, Overhang Parapets, Chimneys
SANTA ROSA/ Myers (1981)	Y	N	Not explicit, all on alluvial fill	Not explicit, no potential for liquefaction or surface faulting	Y	Y	Y
LONG BEACH/ Wiggins and Moran (1971)	Y	Y	Y	N	Y	Y	Y
NBS 61/ Culver et al. (1975)	Y, noted	Proximity to adjacent buildings noted, separation joints noted	Proximity to adjacent buildings noted	Y Fault rupture liquefaction (implicit fault location noted)	Y, noted and rated	Y, noted and rated	Y, noted and rated

Table 5
PERSONNEL ASPECTS

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
CITY OF REDLANDS/ Mel Green & Assoc. (1986)	Not available	Y	Y	Y	N	N	N
SAN FRANCISCO/ Frank Lew	15 min per building	Y	Y	Y	N	N	N
ABAG/ J. Perkins	5 min per building, Very little information noted	Y	Y	Y	Y	Y	N
STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986)	Experienced structural engineer	Y	Y	Y	N	N	N
LOW-RISE/ Wiggins and Taylor (1986)		Y	Y	Y	N	N	N
PALO ALTO/ F. Herman	15 min per building	Y	Y	Y	Y	Y	N

Table 5
(continued)

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
OAKLAND/ Arnold, Eisner (1980, 1984)	20 min per building	Y	Y	Y	N	N	N
MULTIHAZARD/ FEMA & Reitherman et al. (1984)	1 hour to 3 days per building	Y	Y	Y	N	Y	N
NEW MADRID/ Allen & Hoshall (1983)		N	Y	N	N	N	N
OSA HOSPITAL/ (1982)	1-2 days per building	N	Y	Y	N	N	N
LOS ANGELES (1978-79)	40 min per building	Y	Y	Y	N	Y	N
UNIVERSITY OF CALIFORNIA/ McClure (1984)	20 min per building	N	Y	N	N	N	N
SANTA ROSA/ Myers (1981)	1/2 day ($500) per building	Y	Y	Y	N	N	N
LONG BEACH/ Wiggins and Moran (1971)	Professional engineer	N	Y	N	N	N	N

Table 5
(continued)

PROCEDURE/ Source	Survey personnel Approximate person-hours per building	Local Building Officials	Professional Engineers	Registered Architects	Building Owners	Emergency Managers	Interested Citizens
NBS 61/ Culver et al. (1975)	1 hour per building	Y	Y	Y	N	N	N

5
RECOMMENDED RAPID VISUAL SCREENING PROCEDURE

This section presents and discusses the elements of a recommended RSP, based on the results of the survey discussed above.

5.1 Elements of the Recommended RSP

In response to the conclusions (Section 4.7) reached from the survey of RSPs, an RSP employing the following elements is recommended:

- The Effective Peak Acceleration (EPA) values contained in the National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985), defined by Map Area, as an explicit measure of the ground motion.
- The building types contained in ATC-14 (i.e., wood frame, 5 steel types, 3 reinforced concrete, 2 pre-cast, 2 reinforced masonry, and 1 unreinforced masonry types).
- A systematic, simple structural hazard analysis scheme, based on a non-arbitrary measure of building performance for the specific building given the occurrence of the EPA. This scheme consists of a Basic Structural Hazard score, modified by penalties and bonuses to account for perceived deficiencies or strengths because of such factors as design level (inferred from age), condition, and configuration. The scheme involves only simple arithmetic, the score and penalties being added, to arrive at a final Structural Score S (A high score corresponds to a low structural hazard, or is "good," and vice-versa.) The resulting S will relate back to the physical performance of the building, in terms of damage. (The basis for S is discussed further below).
- A simple clipboard data collection form, with space for:
  - a photograph of the building
  - a field sketch of the building
  - data from pre-field visit information (e.g., a summary from the Assessor's or other files, giving address, age, value, or owner's name, perhaps printed on a peel-off label that can be affixed directly to the data collection form)
  - a checklist of items (so that significant items are not omitted), with almost all input to be noted by circling of the appropriate item (so that standard notation is employed)
  - the simple calculation for S

This form and process is to be accompanied by a handbook (ATC-21) explaining its use and providing

- information on how to determine which of the building types is most appropriate for the particular building being surveyed
- explanations and guidance as to the recognition of various significant factors, such as pounding, poor configuration, or soft stories

- a summary sheet of basic information, for quick reference in the field

5.2 Basis for Structural Hazard Scores

It has been emphasized in the above that the Structural Hazard score should be rationally based and physically meaningful. It is recommended that it should be *a measure of the probability of major seismic damage to the building*. Major damage is taken to be direct physical damage being 60% or greater of the building value. (Note: definitions of building value, and related terms are similar to those in report ATC-13, (ATC, 1985), "*Earthquake Damage Evaluation Data for California*").

Sixty percent as heavy damage is selected because (i) it is the lower end of the Major Damage State in ATC-13, (ii) if 60 percent of a building's value is damaged, experience has shown that demolition rather than repair often ensues, and (iii) if 60 percent damage is selected, then most buildings likely to collapse will be included in this category, so that life-safety-related hazardous buildings (due to shaking) are probably all captured.

By employing NEHRP EPA values as the measure of ground motion, ATC-13 relations can be used to determine the probability of occurrence of 60 percent or greater damage, given that input ground motion (see Appendix B for details). The determination of the Basic Structural Hazard score then is:

Basic Structural Hazard score =
–log (probability of damage >= 60%) (1)

If the probability of the damage exceeding 60%, given the NEHRP EPA value for the building's site, is, for example, .001, then the Basic Structural Hazard score is 3. If the probability is .01, then it is 2, and so on.

- Although quite simple, the Basic Structural Hazard score is thus intuitively satisfying. A relatively "safe" building would have values of 3 to 5 in California, whereas the identical building would score approximately 7 to 10 in NEHRP Map Area 3, corresponding to New England or the South Carolina regions, as it is likely to experience less severe ground motion. Note, however, that because many buildings in less seismic areas are not designed for earthquake on the same basis as in California, when this is taken into account the resulting score is more consistent for the same building type in different NEHRP map areas (e.g., in the range of 3 to 5). Values of the Basic Structural Hazard score are provided in Table B1, Appendix B.
- The Basic Structural Hazard score can be easily and directly related back to the probability of major physical damage (i.e., damage exceeding 60 percent of building value).
- The Basic Structural Hazard score will likely prove of value in community cost-benefit decision making because it can be directly related to physical damage.
- The ability to relate Basic Structural Hazard score to physical damage has the further virtue of providing a rational analytical basis for quantifying structural penalties for factors such as age, and configuration. If the impact of these factors on the likelihood (or probability) of major damage can be quantified, then the logarithm of this quantity is the modifier. Although lack of data and the present state of the art may preclude general quantification of the effect of a factor such as "soft story" at present, as new data emerge on the effect of this factor, its quantification can be directly related to a penalty on the Basic Structural Hazard score. In the interim, discussion and expert opinion/elicitation regarding the effect of this factor can take place within the framework of

trying to quantify the impact of this factor on the probability of major damage.

5.3 Data Collection Form

This section discusses the layout and use of data collection form, which is shown in Figure 1. The form would be carried in the field in a binder or clipboard.

Basic Information

Space is provided in the upper right of the form for basic information, much of which might be collated and printed out prior to the field visit. Information desired includes address, zip code (although often lacking from the studies reviewed, this is a useful item), the date of the survey, and identity of the surveyor. Additional useful information about the building such as age, construction type, soil type, and value is also desirable. Preferably, such information should either be computer-printed out directly onto the form, or onto a peel-off label applied by the field surveyor. This information would be quickly entered or affixed as the first item upon coming to the building.

Photograph

A general photo of the building should be taken, showing two sides of the building, if possible. (This would preferably be an "instant" type photo, to avoid the task of later collating photos with forms.)

Sketch

The surveyor would then sketch the building (plan and elevation, or oblique view) indicating dimensions, facade and structural materials, and observed special features such as cracks, lack of seismic separation between buildings, roof tanks, cornices, and other features. This sketch is important, as it requires the surveyor to carefully observe the building.

Building Information

Following this, the surveyor would fill in additional basic information specific to the building such as number of stories; an estimate of the building age (e.g., 1930's or late 1960's), the occupancy (e.g., residential, office, retail, wholesale/warehouse, light industrial, heavy industrial, public assembly such as auditoria or theaters, governmental); and an estimate of the number of persons typically in the building under normal occupancy. For example, for a residence, this would be the number of persons living there (not the daytime population); for an office this would be the daytime population; for a theater this would be the seating capacity.

Basic Structural Hazard Score

Next, based on observation, the surveyor would make a determination of the primary structural material (wood, steel, concrete, pre-cast, reinforced masonry or unreinforced masonry) and circle the appropriate Basic Structural Hazard score. The basis for determination of Basic Structural Hazard scores are given in Appendix B. The building types follow the building category scheme of ATC-14 (ATC, 1987).

Wood

W = wood (low-rise (LR) only, W1 and W2 treated together)

Steel

S1 = moment resisting frame
S2 = steel frame with steel bracing
S3 = light metal (LR only)
S4 = steel frame with concrete shear walls
S5 = steel frame with unreinforced masonry infill walls

Concrete

C1 = moment resisting frame
C2 = shear wall
C3 = concrete frame with unreinforced masonry infill walls

Precast

PC1 = tilt-up (LR only)
PC2 = precast concrete frames

Reinforced Masonry

RM = reinforced masonry buildings of all types, differentiated only by height

Unreinforced Masonry

URM = unreinforced masonry bearing wall (LR and mid-rise (MR) only).

Any specific jurisdiction corresponds to one NEHRP Map Area, and the form used in the field for that jurisdiction would have Structural Scores corresponding only to that Map Area/jurisdiction. All NEHRP Map Areas and corresponding Structural Scores would be furnished in the Handbook.

Confidence

If in doubt as to which category is most appropriate for a particular building, the surveyor should record the possible categories and mark them with an asterisk (*) to indicate the subjective evaluation.

If the surveyor cannot narrow the estimate to two alternates, DNK = Do Not Know should be indicated, signifying that the basic structural material or system cannot be identified from the street. DNK would also apply for a building of mixed construction, where no one category predominates. DNK constitutes a default, indicating that the building and drawings should be reviewed in detail.

Modifiers

Negative modifiers corresponding generally to deficiencies such as poor configuration, pounding, and potential for a neighboring building collapsing onto this building (this penalty would depend on the Basic Structural Hazard score for the neighboring building being sufficiently low as to indicate a potential for collapse, and the height and proximity of the neighboring building being such as to indicate that collapse might affect the subject building).

Soil Profile

Modifiers assigned for adverse soil conditions when the soil profile can be identified with some confidence. Soil profiles have been defined according to the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985):

SL1: Rock or stiff soils less than 200 feet deep overlying rock

SL2: Deep, cohesionless soil or stiff clay conditions exceeding 200 feet depth

SL3: Soft- to medium-stiff clays and sands, exceeding 30 feet in thickness

Structural Score S

Lastly, the Structural Score S is computed by simple addition of the modifiers to the Basic Structural Hazard score. The final Structural Score S is recorded.

5.4 Use of the Results

For any building, the final Structural Score S will typically be a number between 0 and 5 or more, depending on NEHRP Map Area. All buildings surveyed can thus be ranked according to S, and a decision made as to a "cut-off" S. Buildings that score below the cut-off would be subjected to more detailed review. Scoring above the cut-off does not signify a "safe" building, but instead indicates that for the particular community the building is assumed sufficiently safe, and no further review is required.

An appropriate value for the cut-off S is a complex decision, involving financial and ethical questions. Appendix C provides recommendations for a cut-off S. This recommendation should be reviewed and, if necessary, modified by a jurisdiction, as the decision has cost implications. (That is, a relatively high cut-off involves detailed review of a large number of buildings, with increased costs and presumably eventual increased seismic safety, assuming buildings determined to be unsafe are cited and abated. A lower cut-off has lower costs for building review, but may involve lower resulting seismic safety.)

ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________________

______________________ Zip__________

Other Identifiers ______________________

No. Stories ____________ Year Built __________

Inspector ________________ Date __________

Total Floor Area (sq. ft) ______________

Building Name ______________________

Use ______________________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY	
Residential	No. Persons
Commercial	0–10
Office	11–100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

☆ = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	4.5	4.5	3.0	5.5	3.5	2.0	3.0	1.5	2.0	1.5	3.0	1.0
High Rise	N/A	-2.0	-1.0	N/A	-1.0	-1.0	-1.0	-0.5	N/A	-0.5	-1.0	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5
Soft Story	-1.0	-2.5	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE												

COMMENTS

Detailed Evaluation Required?

YES NO

ATC-21-1 32038.01

Figure 1. Data Collection Form

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APPENDIX A

SAMPLE DATA SHEETS

DC-1

DATA COLLECTION FORM
NATURAL HAZARDS EFFECTS
(Extreme Winds, Earthquakes)

A. GENERAL DATA

*1. Facility No. ________ 2. Building Name ________________________________

3. Address ____________________________________ 4. City ____________________

5. State ____________________ 6. Zip Code ________ 7. Year Built ________

8. Date of Major Modifications or Additions, if any _________________________

9. Building Code Jurisdiction: City ☐ County ☐ State ☐ Federal ☐

*10. Latitude ________________________ *11. Longitude _____________________

12. Current Bldg. Use _____________ Orig. Bldg. Use ____________________

13. Basement Yes ____ No ____ Number of Basements ____________________

No. of Stories Above Basement ________________ (See also Item A23)

14. Height of First Story ____________________ ft.

15. Upper Story Height _____________ ft. Special Story Height _________ ft.

16. Is the exterior of first story different from upper stories?

Street Front Side Yes ____ No ____ Other Sides Yes ____ No _____

17. Approximate Roof Overhang Distance ____________ Side _________________

18. Proximity to Adjacent Buildings: Sketch Below with North Arrow

North Side _______ South Side _______ East Side _______ West Side ______

Note Street or Alley Sides ____

*To be filled in by Field Supervisor.

Sketch

DC-2

19. Are plans available? ______ If so, where obtainable ____________________

____________________ Are original calculations available? ______ If so,

where obtainable ____

Name of: Architect ____________________ Engineer ____________________

Contractor ____

Regulatory Agency ____

20. Basic Building Plan

a. Sketch overall plan.
b. Locate shear walls, if any.
c. Locate main frames.
d. Locate expansion joints, if any.
e. Give approximate north arrow and label sides "A", "B", "C", "D", etc. Show street or alley sides.
f. Note any common or party walls.
g. If plan changes in upper floors, sketch this plan and note level of change.

(Use additional sheet if necessary)

DC-3

21. Elevation of Exterior Walls.

Sketch:
- a. All openings or note pattern of openings.
- b. Note exterior finish and appendages.
- c. Note material of walls.
- d. Major cracks or other damage. (Note if cracks are larger at one end.)
- e. Note previously repaired damage.
- f. Note any evidence of damage to cladding or appendages.

(Use additional sheet if necessary)

DC-4

22. Elevation of Interior Shear Walls.

Sketch: a. All openings.
b. Major cracks or other damage. (Note if cracks are larger at one end.)
c. Note any previously repaired damage.

DC-5

23. Adaptability of Basement to Storm Shelter.

a. Floor Over Basement - Concrete ☐ Other ☐

b. If concrete, give thickness ________

c. Available Space (approximate) ______________ sq. ft.

d. Dangerous Contents. Storage of Flammable Liquids ☐

Presence of Transformers or Other Dangerous Equipment ☐

Other Hazards ____

None ☐

24. Is this a Vault-like Structure? Yes ☐ No ☐

DC-6

25. EXTERIOR WALL SUMMARY SHEET

Exterior Characteristics	Side A	Side B	Side C	Side D
Extensive Architectural Ornaments or Veneer				
WALLS Metal Curtain Wall				
Precast Concrete Curtain Wall				
Stone				
Brick				
Concrete Block				
Concrete				
Other				
For Concrete Block and Brick, indicate R for Running Bond S for Stacked Bond				
Condition of Wall*				
OPENINGS Percent of Open Area per Story				

*1. No cracks, good mortar.
2. Few visible cracks.
3. Many cracks
4. Evidence of minor repairs.
5. Evidence of many repairs.

DC-7

B. SITE RELATED INFORMATION

1. Exposure

a. Centers of large city [ ] b. Very rough hilly terrain [ ]

c. Suburban areas, towns, city outskirts, wood areas, or rolling terrain [ ] d. Flat, open country [ ]

e. Flat coastal belts [ ] f. Other [ ]

2. Topography

a. Building on level ground [ ] b. Building on sloping ground [ ]

c. Building located adjacent to embankment [ ]

*3. Geologic formation ______________________________

*4. Location of known faults: Name ____________________ Miles ______

______________________________ Miles ______

*5. Depth of water table ________ ft. When measured: ____________
(Month) (Year)

*6. Depth of bedrock ____________ft.

*7. Soil type ______________________________

*8. Bearing capacity ____________ p.s.f., or ____________ blows per inch

9. Proximity to potential wind-blown debris - Type ____________________

Location ______________________________ Distance ____________

*To be filled in by Field Supervisor.

DC-8

C. STRUCTURAL SYSTEMS

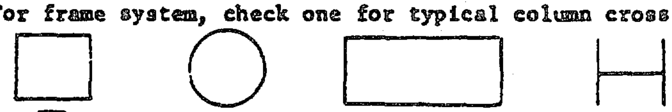
1. Material

Concrete ☐ Masonry ☐ Steel ☐ Wood ☐

2. Vertical Load Resisting System

Frame ☐ Bearing Wall ☐ Wall and Pilasters ☐

For frame system, check one for typical column cross-section



☐ ☐ ☐ ☐ Other ☐

3. Lateral Load Resisting System

Masonry Shear Wall ☐

Concrete Shear Wall ☐

Plywood Shear Wall ☐

Braced Frame ☐

Moment Resisting Frame ☐

Are resisting systems symmetrically located? ☐ Yes ☐ No

4. Floor System

Frame

Concrete Beams ☐

Steel Beams ☐

Steel Bar Joist ☐

Wood Beams ☐

No Framing Members ☐

Precast Concrete Beams ☐

Deck

Concrete Flat Plate ☐

Concrete Flat Slab ☐

Concrete Waffle Slab ☐

Steel Deck ☐

Wood Joists ☐

Wood Plank ☐

Straight Sheathing ☐

Plywood Sheathing ☐

Diagonal Sheathing ☐

Precast Concrete Deck ☐

Concrete Joists ☐

Concrete Plank ☐

Note if concrete topping slab is used over metal decks or concrete plank.

BC-9

Connection Details

	Framing	Decking To Framing
Bolted	☐	☐
Welded	☐	☐
Metal Clips	☐	☐
Wire Fastener	☐	☐
No Connection	☐	☐
Nailed	☐	☐
Metal Hangers	☐	☐

Anchorage Floor to Walls

Type ____________________

Spacing ____________________

5. Roof System

Frame

Concrete Beams	☐	Steel Truss	☐
Steel Beams	☐	Wood Truss	☐
Steel Bar Joist	☐	No Framing Members	☐
Wood Beams	☐	Precast Concrete Beams or Tees	☐
Wood Rafters	☐		

Deck

Concrete Flat Slab	☐	Concrete Waffle Slab	☐
Metal Decking	☐	Plywood Sheathing	☐
Concrete Slab	☐	Diagonal Sheathing	☐
Concrete Joists	☐	Straight Sheathing	☐
Precast Decking	☐	Concrete Fill	Yes ☐ No ☐

DC-10

Connection Details

	Framing	Decking to Framing
Bolted	☐	☐
Welded	☐	☐
Metal Clips	☐	☐
Wire Fastener	☐	☐
No Connection	☐	☐
Nailed	☐	☐
Metal Hangers	☐	☐

Anchorage Roof to Walls

Type ______________________________

Spacing ______________________________

D. NONSTRUCTURAL ELEMENTS

1. Partitions

Type

	Typical	Corridor
Partial Height	☐	☐
Full Height Floor-To-Ceiling	☐	☐
Floor To Floor	☐	☐
Movable	☐	☐

Composition

Lath and Plaster ☐

Gypsum Wallboard ☐

Concrete Block ☐

Clay Tile ☐

Metal Partitions ☐

DC-11

2. Ceiling

Typical Room

Material

Acoustical Tile ☐ Gypsum Board ☐ Plaster ☐

Method of Attachment

Suspended ☐ Metal Channels ☐ Tee Bar Grid ☐

Attached Directly to Structural Elements ☐

Typical Corridor

Material

Acoustical Tile ☐ Gypsum Board ☐ Plaster ☐

Method of Attachment

Suspended ☐ Metal Channels ☐ Tee Bar Grid ☐

Attached Directly to Structural Elements ☐

3. Light Fixtures

Typical Room

Recessed ☐ Surface Mounted ☐ Pendant (Suspended) ☐

Typical Corridor

Recessed ☐ Surface Mounted ☐ Pendant (Suspended) ☐

4. Mechanical Equipment

Location of Mechanical Equipment Room

Basement ☐ Other Floor ☐ Which Floor ________

Roof ☐

Is Equipment Anchored to Floor? No ☐ Yes ☐

Location of The Following Units

Liquid Storage Tank ______________________________

Cooling Tower ______________________________

Air Conditioning Unit ______________________________

DC-12

5. Roofing

Description

Flat ☐ Arched ☐ Gabled ☐ If arched or gabled, sketch section.

Pitched ☐ Slope (:12)

Parapet No☐ Yes ☐ Height (______ ft. ______in.) Thickness (_____in.)

Material ______________ Special Anchorage or Bracing Yes ☐ No ☐

Type

Built-up gravel ☐ Gravel ☐ Asphalt or Wood Shingles ☐

Clay Tile ☐ Other ☐

6. Windows

Type

Fixed ☐ Movable ☐

Frame Material:

Aluminum ☐ Steel ☐ Stainless Steel ☐ Wood ☐

Size: Average Size of Casing (____ ft. x _____ ft.)

Average Size of Glazing (____ ft. ____ in. x ____ ft. ____ in.)

How Casing is Attached to Structure

Bolted ☐ Screwed ☐ Clipped ☐ Welded ☐ Nailed ☐

Glazing Attachment to Casing

Elastomeric Gasket ☐ Glazing Bead ☐ Aluminum or Steel Retainer ☐

Other ☐

7. Gas Connection

Flexible Connection to Building ☐ Rigid Connection to Building ☐

Automatic Shut-off ☐ None ☐ Unknown ☐

INSPECTED BY ______________________________

DATE ______________________________

FIELD SUPERVISOR ______________________________

FORM FMA-1

FACILITY NO. ________ EXPECTED SITE MODIFIED MERCALLI INTENSITY ________

FIELD EVALUATION METHOD

STRUCTURAL SYSTEMS - EARTHQUAKE AND WIND RATING

VERTICAL RESISTING ELEMENTS							
Type	General Rating (GR) E	General Rating (GR) W	Symmetry (S)	Quantity (Q)	Symmetry Quantity Rating (SQR) [1]	Present Condition (PC)	Sub-Rating (SR1) [2]
TRANSVERSE LOADING							
LONGITUDINAL LOADING							

FOOTNOTES:

1. Symmetry-Quantity Rating (SQR) = $\frac{S + Q}{2}$.
2. Sub-rating SR-1 = $\frac{SQR + 2PC}{3}$.

	TYPE	GENERAL RATING (GR) Earthquake	GENERAL RATING (GR) Wind
A	Steel Moment Resistant Frames	1	1
B	Steel Frames - Moment Resistance Capability Unknown	2	2
C	Concrete Moment Resistant Frames	1	1
D	Concrete Frames - Moment Resistance Capability Unknown	2	2
E	Masonry Shear Walls - Unreinforced	4	2 or 3
F	Masonry or Concrete Shear Walls - Reinforced	1	1
G	Combination - Unreinforced Shear Walls and Moment Resistant Frames	2	2
H	Combination - Reinforced Shear Walls and Moment Resistant Frames	1	1
J	Braced Frames	1	1
K	Wood Frame Buildings, Walls Sheathed or Plastered	1 or 2	2 or 3
L	Wood Frame Buildings, Walls Without Wood Sheathing or Plaster	4	4

SYMMETRY (of Resisting Elements)	
1	Symmetrical
2	Fairly Symmetrical
2 or 3	Symmetry Poor
3 or 4	Very Unsymmetrical

NOTE: Add 1 (not to exceed 4) to each rating if a high degree of vertical non-uniformity in stiffness occurs.

QUANTITY (of Resisting Elements)	
1	Many Resisting Elements
2	Medium Amount of Resisting Elements
3	Few Resisting Elements
4	Very Few Resisting Elements

NOTE: If exterior shear walls are at least 75% of building length, this rating will be 1.

PRESENT CONDITION (of Resisting Elements)	
1	No Cracks, No Damage
2	Few Minor Cracks
3	Many Minor Cracks or Damage
4	Major Cracks or Damage.

NOTE: If masonry walls, note quality of mortar - good or poor. If lime mortar is poor, use next higher rating.

FACILITY NO. ______________

FORM FMA-2

FIELD EVALUATION METHOD

STRUCTURAL SYSTEMS - EARTHQUAKE AND WIND RATING

HORIZONTAL RESISTING ELEMENTS						
Type		Rigidity (R)	Anchorage & Connections (A)	Chords (C)		Sub-Rating (SR2)
				Longitudinal	Transverse	
Roof						
Floors						

Note: Sub-rating SR2 = Largest of R, A or C.

Type
A Diaphragm
B Steel Horizontal Bracing

Rigidity - Ratings
1. Rigid
1.5 Semi-rigid
2.0 Semi-flexible
2.5 Flexible

Anchorage and Connections - Ratings
1 Anchorage confirmed - capacity not computed, but probably adequate.
2 Anchorage confirmed - capacity not computed, but probably inadequate.
3 Anchorage unknown.
4 Anchorage absent.

Chords - Ratings
1 Chords confirmed, but capacity not computed.
2 Chords unknown, but probably present.
3 Chords unknown, but probably not present.
4 Chords absent.

FACILITY NO. ____________________ FORM FMB-1

FIELD EVALUATION METHOD

EXIT CORRIDOR AND STAIR ENCLOSURE WALLS - EARTHQUAKE RATING

TYPE OF WALL	REINFORCEMENT			ANCHORAGE					WALL RATING
	Present	Not Present	Not Known	Mortar Only	Dowels	Screws or Bolts	Other	Not Known	
Brick									
Brick									
Concrete Block									
Concrete Block									
Reinforced Concrete									
Tilt-up or Precast Concrete									
Steel Studs & Plaster									
Wood Studs & Plaster									
Hollow Tile									
Hollow Tile & Plaster									

NOTE: Wall Rating on Basis of A, B, C, and X.

FORM FMB-1

FACILITY NO. ______________

FORM FMB-2

FIELD EVALUATION METHOD

OTHER LIFE HAZARDS - EARTHQUAKE RATING

TYPE OF RISK	RATING
Partitions Other Than on Corridors or Stair Enclosures	
Glass Breakage	
Ceiling	
Light Fixtures	
Exterior Appendages and Wall Cladding*	

Ratings
A = Good
B = Fair
C = Poor
X = Unknown

*A description of some of the ratings for Exterior Appendages and Wall Cladding are:

Description	Rating
Spacing of anchors appears satisfactory	A
Size and embedment of anchors satisfactory	A
Spacing of anchors appears to be too great	B
Size and embedment of anchors appears unsatisfactory	C
Anchorage unknown	X
Anchorage corroded or obviously loose	C
No anchorage	C

EARTHQUAKE GAS CONNECTION		
Present	Not Present	Not Known

FACILITY NO ______________ FORM FME

FIELD EVALUATION METHOD

CAPACITY RATIOS - EARTHQUAKE AND WIND RATING

	General Rating (GR)	Sub-Rating SR1	Sub-Rating SR2	Basic Structural Rating*	Capacity Ratio**
EARTHQUAKE					
WIND					

*Basic Structural Rating = $\frac{\text{GR + 2 (Largest of SR1 or SR2)}}{3}$.

**Capacity Ratio for wind shall be obtained from Form FMC-1. For earthquake, the ratio is obtained from the Basic Structural Rating divided by the Intensity Level Factor at the site as determined from the table below.

Modified Mercalli Scale	Intensity Level Factor
VIII or Greater	1
VII	2
VI	3
V or Less	4

A description of Modified Mercalli Scale is included on table 3.3.

Capacity Ratio Rating	
Capacity Ratio	Rating (In Terms of Risk)
Less than 1.0	Good
1 through 1.4	Fair
1.5 through 2.0	Poor
Over 2.0	Very Poor

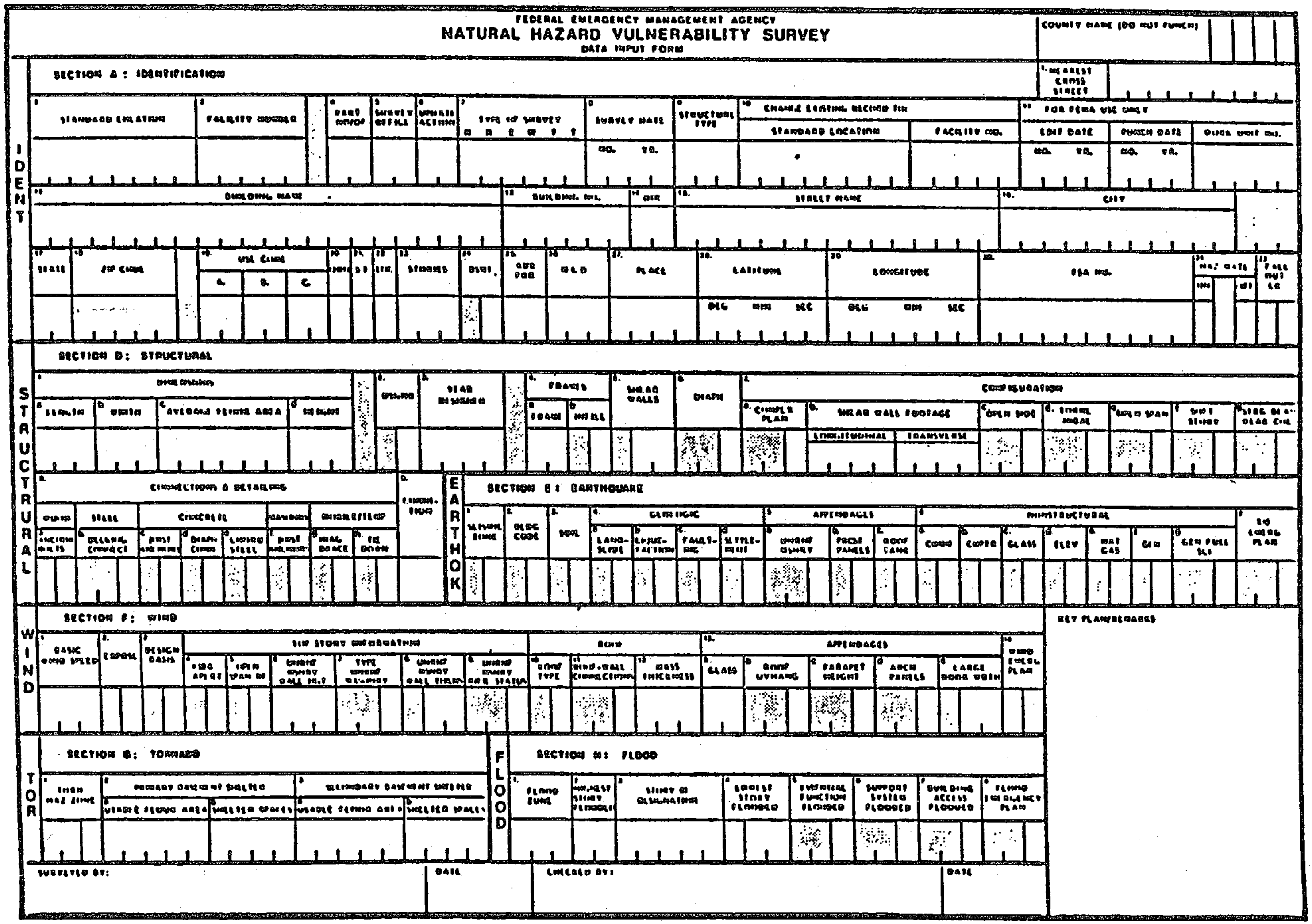


Fig. 1-2. Multi-Hazard DIF.

A. IDENTIFICATION

9. STRUCTURE TYPE (Enter Number)

1. Quonset, steel frame
2. Wood frame
3. Wall bearing
4. Steel frame
5. Reinforced-concrete frame
6. Steel/concrete frame
7. Tunnels
8. Mines

Type floor & roof

1. Wood joist
2. Wood/steel joist, shallow truss
3. Glulam
4. Precast concrete
5. Reinforced concrete slab
6. Flat plate
7. Metal deck/steel frame
8. Metal deck/open-web bar joist
9. Lightweight tension structure

Type walls

1. Masonry, unreinforced
2. Masonry, reinforced
3. Reinforced concrete
4. Precast concrete
5. Infill masonry
6. Corrugated-metal
7. Arch cladding
8. Wood sheathing
9. Stucco
0. Glass

24. BASEMENT
0. No basement

Wood
1. Wood joists
2. Plywood I-joist
3. Glulam
4. Heavy timber

Concrete
5. One-way joists or slab
6. Flat plate
7. Flat slab
8. Two-way slab
9. Waffle slab
10. Precast

Combination
11. Steel joist/concrete slab
12. Steel frame/concrete slab
13. Wood/steel joists

D. STRUCTURAL

4. FRAMES (Enter Number)

a. Frame class

Wood
1. Timber/pole
2. Braced frame

Steel
3. All metal
4. Pinned
5. Moment-resistant
6. Ductile moment-resistant
7. Braced frame

Concrete
8. Pinned
9. Slab/plate
10. Moment-resistant
11. Ductile moment-resistant
12. Braced frame

Lightweight tension structure
13. Tension structure

b. Infill class
0. Not infilled
1. Infill/partial infill unreinforced or partially reinforced masonry
2. Infill/partial infill reinforced masonry

5. SHEAR WALLS (Enter Number)

Wood
1. Plywood
2. Non-plywood

Steel
3. Plate

Masonry
4. Ordinary unreinforced
5. Monumental unreinforced
6. Partially reinforced
7. Reinforced

Concrete
8. Poured-in-place
9. Precast

Mobile/Temporary
10. Mobile/Temp Module

6. DIAPHRAGMS (Enter Number)

Wood
1. Plywood
2. Non-plywood

Steel
3. Metal decking or diagonally braced

Concrete
4. Reinforced
5. Precast
6. Unreinforced
7. Lightweight tension structure

7. CONFIGURATION
(Yes/No/0 = does not apply)

8. CONNECTIONS AND DETAILING
(Yes/No/0 = does not apply)

9. CONDITION (Enter Number)

1 = good
2 = slight deterioration
3 = major deterioration

E. EARTHQUAKE

2. BUILDING CODE (Enter Number)

1. No seismic design
2. Some seismic design
3. UBC 1949-1970
4. UBC 1973+
5. Above average criteria

3. SOIL
(S = soft, H = hard)

4. GEOLOGIC
0 = no data
1 = low hazard
2 = intermediate
3 = high

5. APPENDAGES
(Yes/No/0 = no data)

6. NONSTRUCTURAL
X = not present
0 = no data
B = braced
U = unbraced

7. EARTHQUAKE PLAN
(Yes/No/0 = no data)

F. WIND

2. EXPOSURE
(A or B)
A. Protected
B. Open

3. DESIGN BASIS
(Enter Number)
1. No wind design
2. Some wind design
3. Code, 1961-1975
4. Code, 1976+

7. MASONRY TYPE
(Enter Letter)
a. Clay brick
b. Clay tile
c. Concrete block
d. Concrete brick
e. Adobe
f. Stone

9. INFILL
(Enter Number)

0 = no infill
1 = partial
2 = infill

10. ROOF
(Enter Number)

1. Plywood
2. Non-plywood
3. Metal decking
4. Reinforced concrete
5. Precast
6. Unreinforced concrete
7. Lightweight tension structure

11. ROOF/WALL CONNECTION
(Enter Number)

0. No data
X. No connection
1. Plywood
2. Non-plywood
3. Metal decking
4. Reinforced
5. Precast concrete
6. Unreinforced concrete

13. APPENDAGES
(Enter Letter)

a. Glass (%)
b. Overhang (ft)
c. Parapet height (ft)
d. Arch panels (Yes/No)
e. Large door width (ft)

14. WIND EMERGENCY PLAN
(Yes/No/0 = no data)

G. TORNADO SHELTER

1. TORNADO ZONE (Enter Number)

1 = lower risk
2 = higher risk

CONSTRUCTION:	OCCUPANCY:	CONFIGURATION:	CONTENTS:
F-RC-HI TYPE	03/15 USE CODE	4 # STORIES	X HAZARDOUS
___PRE 1939	___VITAL	65 x 200 SIZE	___IMPORTANT
___PRE 1973	___HIGH DENSITY	___CMPLX PLAN	
1920 DATE	___VULNERABLE	___CMPLX ELEV	DECORATION:
___RENOVATED	X 8AM-6PM	___SOFT STORY	___HEAVY
______DATE	___6PM-MDNT	___OPEN FRONT	___OVERHANGING PUBLIC WAY
	___MDNT-8AM	H = 45'	

CONSTRUCTION

EXT. WALLS: FACADE______________ SIDES 6" RC

INT. WALLS: BEARING______________ PARTITIONS______________

DIAPHRAGMS: FLOOR______________ ROOF______________

FRAME: ___BRACED; ___MOMENT RESISTING; OTHER:______________

MISC. FIRE PROOF CONST

CONFIGURATION

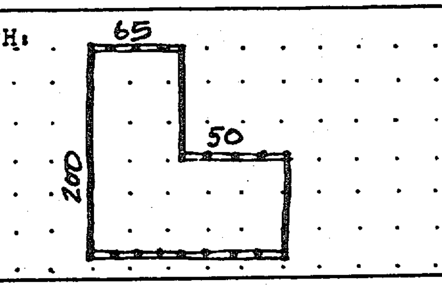
STIFFNESS DISTRIBUTION:

PLAN L- SHAPE

ELEVATION IRREGULAR

MISC.______________

PLAN SKETCH:



FUNCTION AND OCCUPANCY

FLOORS:____-____ USES: WAREHOUSE/OFFICE

FLOORS:____-____ USES:______________

FLOORS:____-____ USES:______________

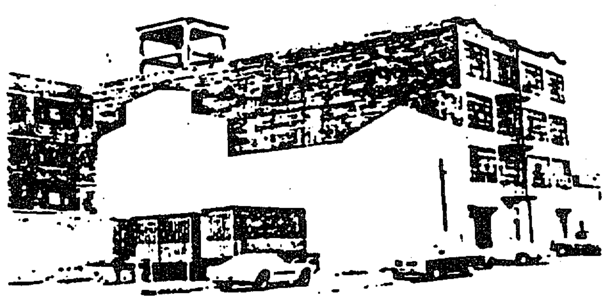


FIGURE A1-2.
Sample Building Information Sheet.

Construction Types Code:

Bearing Wall:

- B-UM Unreinforced Masonry
- B-RM Reinforced Masonry
- B-RC Reinforced Concrete
- B-PC Pre-cast Concrete
- B-WD Wood (stud wall)

Frame:

F-ST-(HI, LI, HC, LC) Steel
F-RC-( ) Reinforced Concrete
F-WD-( ) Wood (glu-lam, heavy timber)

Exterior skin (heavy infill, light infill, heavy curtain, light curtain)

Frame material

Use Codes:

- 01 Apartment
- 02 Hotel
- 03 Office
- 04 Retail
- 05 Restaurant
- 06 Theatre
- 07 Auditorium
- 08 Gymnasium
- 09 Church
- 10 School
- 11 Hospital
- 12 Parking
- 13 Car Servicing
- 14 Manufacturing
- 15 Warehouse
- 16 Public facility
- 17 Public utility

FIGURE A1-3. Key to sample Building Information Sheet.

CRITICAL FACILITIES
FIELD INSPECTION BUILDING DATA SHEET

1. NAME OF BUILDING________________ CENSUS TRACT________
2. BLDG. ADDRESS________________ CITY________ COUNTY_____
3. NO. OF OCCUPANTS____________ DAY______ NIGHT_______
4. YEAR BUILT____________ 5. BLDG. SIZE (SQUARE FEET)_______
6. NO. OF STORIES/FLOOR________ 7. BASEMENT? YES_____ NO_____
8. PRIMARY STRUCTURAL SYSTEM

_______ A. STEEL FRAME
_______ B. STEEL FRAME (REINFORCED CONCRETE SHEAR WALL AROUND CENTRAL CORE)
_______ C. WALL BEARING
_______ D. PRECAST COLUMN AND BEAM
_______ E. REINFORCED CONCRETE FRAME
_______ F. REINFORCED CONCRETE FRAME (REINFORCED CONCRETE SHEAR WALL AROUND CENTRAL CORE)
_______ G. FLAT PLATE CONCRETE SLAB
_______ H. WOOD FRAME
_______ I. PLANK AND BEAM FRAME
_______ J. PRE-ENGINEERED METAL BUILDING
_______ K. OTHER STRUCTURAL TYPES DESCRIBE

____

____

9. FOUNDATION TYPE

_______ A. SPREAD
_______ B. STRIP
_______ C. PILES
_______ D. CAISSONS
_______ E. SLAB ON GROUND
_______ F. OTHER

10. WALL TYPE ________________________
11. FLOOR/ROOF TYPE ________________________
12. SPECIAL FEATURES ________________________

____

13. SPECIAL SOIL CONDITIONS ________________________

____

SINGLE AND MULTI-FAMILY HOUSING DATA SHEET

CENSUS TRACT (DISTRICT) ____________________

ITY ____________ COUNTY ____________

A. SINGLE FAMILY RESIDENCES

1) PREDOMINATE FOUNDATION TYPES
   A. ________ SLAB ON GROUND
   B. ________ POURED CONCRETE OR MASONRY BLOCK FOUNDATION WALL
   C. ________ STONE FOUNDATION WALLS
   D. ________ OTHER

2) PREDOMINATE EXTERIOR WALL, VENEER OR FINISH
   A. ________ BRICK/MASONRY
   B. ________ STONE
   C. ________ WOOD-SIDING OR SHINGLES
   D. ________ STUCCO
   E. ________ OTHER

3) CHIMNEYS, PARAPETS, ORNAMENTATION OR OTHER FALLING HAZARDS ________

4) AGE ________ 5) HEIGHT ________

5) NO. OF OCCUPANTS DAY ________ NIGHT ________

B. MULTI-FAMILY RESIDENCES

1) PREDOMINANT STRUCTURAL TYPE
   A. ________ STEEL FRAME
   B. ________ WALL BEARING
   C. ________ CONCRETE FRAME
   D. ________ FLAT PLATE
   E. ________ WOOD FRAME
   F. ________ PLANK AND BEAM

2) NO. OF OCCUPANTS DAY ________ NIGHT ________

3) AGE ________ 4) HEIGHT ________

5) STORIES/FLOORS ________

CENSUS TRACT ______

NO. OF BLDGS.	COMMERCIAL	PUBLIC NON-EDUCATIONAL	UTILITIES	INDUSTRIAL	EDUCATIONAL
STEEL FRAME					
WALL-BEARING					
CONCRETE FRAME					
FLAT PLATE					
WOOD FRAME					
PLANK AND BEAM					
PRE-ENGINEERED METAL					
1 STORY/FLOOR					
2-5 STORIES/FLOORS					
6-10 STORIES/FLOORS					
OVER 10 STORIES/FLOORS					
AGE PRIOR 1900					
1900-1929					
1930-1949					
1950-1969					
1970-PRESENT					

BUILDING ADDRESS:	BUILDING LOCATION (APN):
NAME OF BUSINESS TENANTS:	OWNERS NAME & ADDRESS:
TYPE OF USE:	NO. OF STORIES: ______ BASEMENT: __________
TYPE OF STRUCTURAL SYSTEM:	
BUILDING SIZE: Square Footage per floor: __________ Total: __________	OCCUPANT LOAD: (UBC-Table 33-A) ______
DATE OF ORIGINAL CONSTRUCTION: __________ DATE OF SUBSEQUENT REMOD./REPAIR AFFECTING THE STRUCTURAL SYSTEM: ______	
NAME OF ORIGINAL DESIGNER: ______________________ NAME OF ORIGINAL CONTRACTOR: ______________________ COMPANY RESPONSIBLE FOR SUBSEQUENT STRUCTURAL MODIFICATION: __________	
HISTORIC BUILDING CATEGORY: ☐ YES ☐ NO	
REMARKS:	

BUILDING ADDRESS: 550 Example * 552	**BUILDING LOCATION (APN):** 120-15-084
NAME OF BUSINESS TENANTS: 550 * 552 *	**OWNERS NAME & ADDRESS:** *
TYPE OF USE: 550 Coffee House 3278 552 Retail Store 3270	**NO. OF STORIES:** 1 **BASEMENT:** No
TYPE OF STRUCTURAL SYSTEM: C.B. & R.C. Beams & Cols. Flat Roof	
BUILDING SIZE: Square Footage per floor: 5475 2250 MEZ. Total: 7725	**OCCUPANT LOAD:** (UBC-Table 33-A) ≈ 100 $\frac{1/2(5475)}{15} + \frac{1/2(5475)}{30} + \frac{2250}{100}$
DATE OF ORIGINAL CONSTRUCTION: 1951 **DATE OF SUBSEQUENT REMOD./REPAIR AFFECTING THE STRUCTURAL SYSTEM:**	
NAME OF ORIGINAL DESIGNER: N/A **NAME OF ORIGINAL CONTRACTOR:** — **COMPANY RESPONSIBLE FOR SUBSEQUENT STRUCTURAL MODIFICATION:** —	
HISTORIC BUILDING CATEGORY: ☐ YES ☒ NO	
REMARKS: *Names omitted in this publication	

BUILDING INSPECTION QUESTIONNAIRE
(Damage Estimation)

INSPECTORS NAME: ______ DATE: 5/9/85

IDENTIFICATION OF STRUCTURE: Bldg. #4

LOCATION: ______ ZONE: UBC 4

SPECIFIED INTENSITY (MMI): IX

Adjacency Factor:

The structure endangers another structure: yes
The structure is endangered by another structure: yes
The structure may be a support for another sturcture: yes
The structure may be supported by another structure: yes

STRUCTURES USE: Residential ______ Commercial ✓ Industrial ______
Special Facility no
Lifelines no

Importance Factor:
Impact of structures' use in the regions' economy in the event of an earthquake. negligible

MISC. DATA: Year Structure Built 1890-1900 No. of Stories 1
Floor area per story 4950 (Square Feet)(w/penthouse)
No. of Occupants: Day 15 Night 0
Potential no. of victims 15
Is there a basement? no
Is there a SANITARY crawl space? no

BUILDING CONFIGURATION: REGULAR ______ Elevation Regularity yes
Plan Symmetry yes
IRREGULAR ✓ Offset center of rigidity maybe
Discontinuity yes

SETBACKS yes

GEOMETRY OF BUILDING (Attach sketches showing overall dimensions, layout, window spacings and sizes): Elevation View ______
Plan View 45' x 110'
Exterior Wall View ______
Typical Shear Wall (core of corner) URM

NO. OF SEPARATION JOINTS:
In Elevation none
In Plan of Superstructure none

EVALUATION	Transverse Direction	Longitudinal Direction
-Plan Symmetry	good average poor	good average poor
-Elevation Regularity	good average poor	good average poor
-Redundancy of Bracing Elements	good average poor	good average poor

SPECIAL CHARACTERISTICS:

BUILDING CLASSIFICATION SYSTEM 2.1.1.a

STRUCTURAL REDUNDANCIES: Frame Line no
Plan no

QUALITY OF CONSTRUCTION:

		Good	Avg.	Poor
Workmanship:	Visual Observation	✓	-	-
	Review of Documentation	-	-	-
	Analytical Studies	-	-	-
Overload History Weakening Structural Resistance:				
	* Due to Earthquake	-	-	-
	Due to Fire	-	-	-
	Due to Extreme Environmental Conditions	-	-	-

QUALITY OF DESIGN: *masonry cracks @ mortar joints

Is design regular or special? regular
Proper consideration of soil condition? unknown
Is it designed for earthquake loading? no
Structural ductility? none
Does as-built structure conform to design? n/a
Original designed base shear (kips)? n/a
Computed existing base shear (kips)? n/a
Ratio of existing to original? unknown

CONSTRUCTION MATERIALS:

Quality of materials used? average
Comparison with original material specs? n/a
Masonry or non-masonry? URM
Reinforced or non-reinforced?

SUPERSTRUCTURE

Continuous concrete wall? no
Concrete columns with infill? no
Large heavy pre-cast structural elements? no
Others masonry pilaster and infill
Any signs of distress?

FOUNDATION: Type? spread
Is soil strength adequate? unknown - probably
(Identify loose sands, sensitive clays, or highly cemented sands clay
Possibility of landslide? no
Possibility of settlement? no - has already occurred
Possibility of sliding? no
Possibility of overturning? no
Possibility of liquefaction? no
Possibility of uplift? no

PRIMARY STRUCTURAL SYSTEM OR ELEMENTS:

Vertical load carrying elements? masonry pilasters
Lateral load carrying elements? URM shear walls

INTERIOR ENVELOPE:

VERTICAL		NON-VERTICAL	
Walls	gypsum	Floors	concrete slab on grade
Doors/Windows	wood/old	Ceilings	gypsum
Others	—	Others	—

EXTERIOR ENVELOPE:

VERTICAL		NON-VERTICAL	
Walls	masonry	Roofs	tin built-up
Doors/Windows	wood/old	Slabs	concrete on grade

EVALUATION:

Some columns added to lower truss chord. A second floor (attic) was then placed on the truss chord.

Possibility of buckling of x-bracings? no
Excessive deflections of long span floors and roofs, etc.? no
Presence of cracks? yes - masonry walls
Excessive compressive force (Possibility of crushing)? no
Additional openings and/or penetrations? no
Possibility of weak column strong beam? no
Additional closures (partitions)? no
Shear wall type and thickness? 8" URM
Is suspended ceiling braced? no

SECONDARY NON-STRUCTURAL SYSTEM OR COMPONENTS:

ARCHITECTURAL:

INTERIOR ELEMENTS		EXTERIOR ELEMENTS	
Lights	hanging fluorescent	Parapets	yes
Ornamentations	much	Ornamentations	no
Finishes	no	Marquees	—
Partitions	gypsum	Overhangs	no
Stairways	timber/old	Balconies	no
Shaftway	—	Chimneys	no
Ceilings	gypsum	Railings	no
Others	—	Roofing	tin w/ built-up over
		Siding	no
		Cladding	no
		Fire Escape	no
		Canopies	no
		Veneers	no
		Others	—

Possibility of collapse of infill materials? yes

SERVICE SYSTEMS:

ELEVATORS: no
Possibility of cage falling? ______
Adequacy of cage guides and motor mountings ______
MECHANICAL forced air gas
ELECTRICAL old
SPRINKLER none
FIRE CONTROL SYSTEM none
FUEL (HVC) natural gas

Are service systems adequate? yes
Are service systems adequately mounted? no
Will they provide service after an earthquake? no
Possibility of failure in fuel system causing fire? slight
Adequacy of fire control system? no
Possibility of explosion? no
Possibility of release of toxic chemicals? no

CONNECTIONS:

Adequacy of connections between primary structural elements to develop shear resistance? poor
Adequacy of connections between secondary non-structural elements to develop shear resistance? poor
Adequacy of connections between primary structural elements and secondary non-structural components to develop shear resistance? poor
Adequacy of foundations connections? unknown

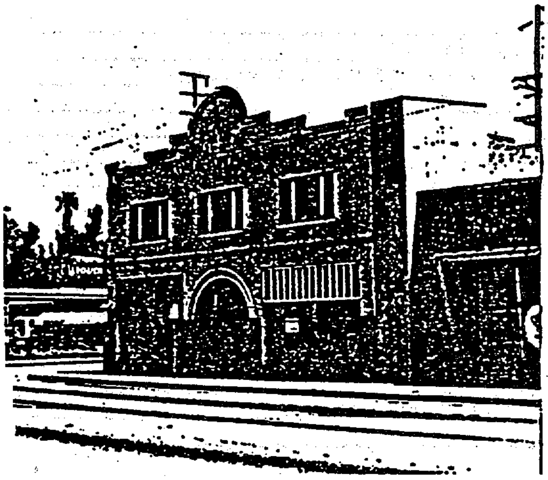
General Remarks:

a. Old URM building with timber roof trusses and sheet metal roof.

b. Reasonably open interior from floor to roof trusses with a few wood stud/gypsum partitions.

c. Trusses poorly attached to masonry pilasters.

BUILDING DATA FORM



ADDRESS:
AREA: TARGET AREA V
BUILDING NAME:
OWNER:
OCCUPANCY TYPE: B-2 AND R-3
TYPE OF CONSTRUCTION: URM, STUCCO
NUMBER OF STORIES: 2
BUILDING HEIGHT: 24 FEET
CONSTRUCTION: 1912
PLANS AVAILABLE: NONE

SUMMARIZE FINDINGS AND RECOMMENDATIONS HERE:

PRESENTLY VACANT. OWNER IS PRESENTLY IN PROCESS OF GUTTING THE BUILDING IN ORDER TO DO SEISMIC RETROFIT AND REMODELING TO OFFICE/COMMERCIAL USESES. INTERIOR WALLS ON SECOND FLOOR REMOVED SHOWIG STRUCTURAL LUMBER AND INTERIOR SIDE OF WALLS. OLD WOOD IN GOOD SHAPE. SECOND STORY FLOOR IS DIAGONALLY SHEATHED. NO MAJOR CRACKS OR OTHER STRUCTURAL WEAKNESSES NOTED.

SAMPLE

FIELD DATA

ROOF: FLAT

COVERING HOT-MOPPED TAR

PARAPETS: FRONT - MATERIAL: BRICK QUALITY GOOD MORTAR QUAL. GOOD
THICKNESS 8" HEIGHT 2'-3', 7' AT FRONT BRACED OR BOND BEAM: —
OTHER REINF: NONE

ARCHITECTURAL IMPORTANCE: POTENTIAL - UNIQUE STYLE

SIDE AND REAR WALLS: URM, STUCCO COVERED

CORNICES: MATERIAL: NONE
PROJECTION: —
OTHER OBSERVATIONS: ROOF TILE —
COPING —
TOWERS/CHIMNEYS —
SIGNS 3'x 7' PROJECTED OVER SIDEWALK
TANKS —

ATTIC: HEIGHT: — MATERIAL: —
ANCHORS/BOND BEAMS: —

INTERIOR:
FLOORS: WOOD
INTERIOR WALLS: LATH & PLASTER
FRAMING: 2"x 6"

EXTERIOR:
ABUTTING BUILDINGS: SOUTH SIDE ONLY; TIRE STORE

STREET FRONT CONSTRUCTION: 4 LANE BOULEVARD

ARCHITECTURAL SIGNIFICANCE: POTENTIAL

LINTELS: ARCHED FRONT

THIN FACING OVER FRAMING:

SIGNS OR OTHER HAZARDS: ONE SIGN CANTILEVERED OVER FRONT SIDEWALK

OTHER OBSERVATIONS: EXPOSED BRICK ALONG BACK SIDE

SAMPLE

SUMMARY OF CONSTRUCTION

Exterior Walls:

N STUCCO OVER BRICK E EXPOSED BRICK S ABUTS OTHER BUILDING W 2 LARGE WINDOWS

Notes:

Roof: FLAT

Floor(s): WOOD AND CONCRETE

Interior Walls BEING REMODELED FROM LATH AND PLASTER

Frame Lintels ARCHED

Other: MEZZANENE, 2 STORE FRONT WINDOWS

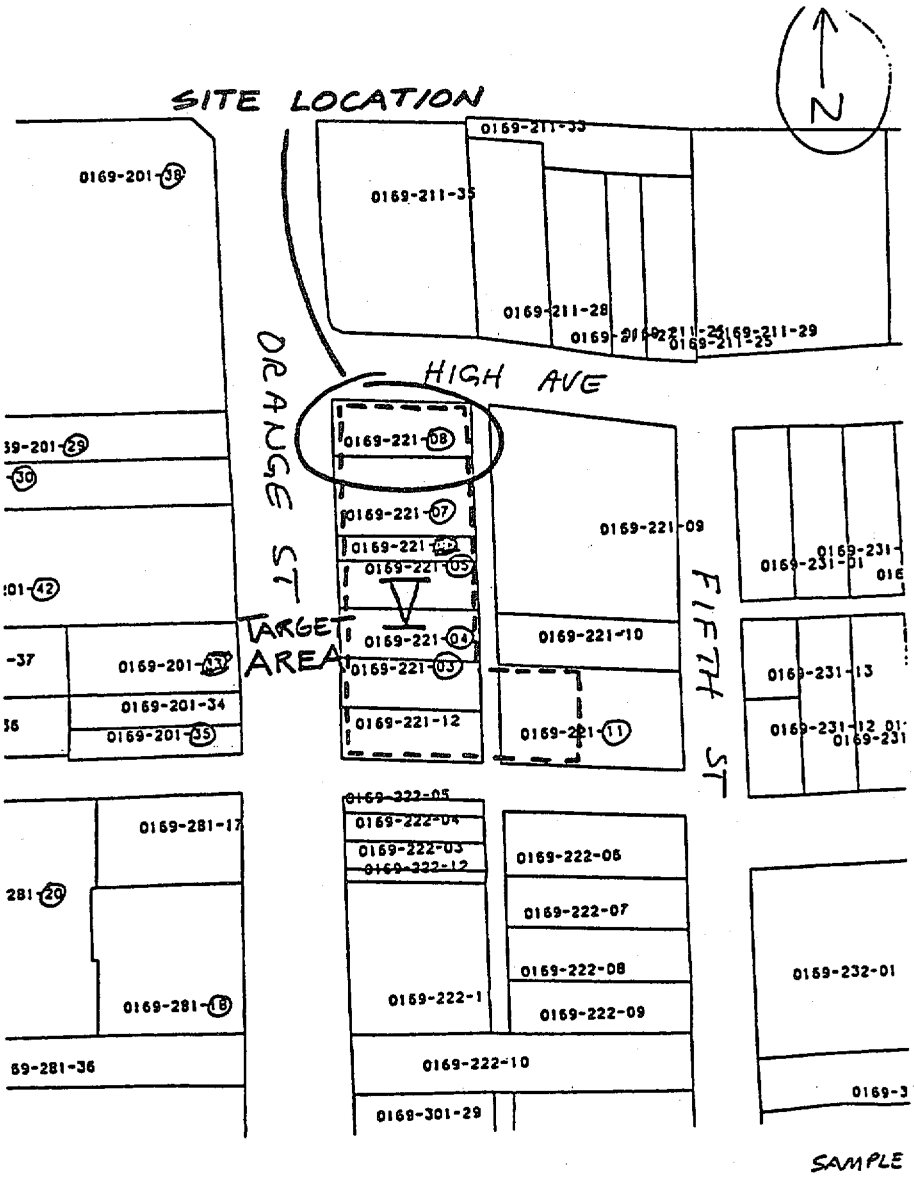
POSSIBLE HAZARDS

X Parapets
Walls
Gables
X Signs
Roof Tile
Coping
Facing
Towers
Marquees
Cornices
Ornamentation
Chimneys Tanks

OTHER NOTES OR REMARKS:

SAMPLE

SKETCHES AND NOTES



CRITICAL FACILITIES
BUILDING STRUCTURE CLASSIFICATION FORM

Name of building ______________________________________
Address ______________________________________
____

Census tract ________

Primary function of building ____________________________

Year built _____ Year remodeled or rehabilited _____

Plan sketch and dimensions:

Building length (parallel to street) L = _______ feet
Building depth (perpendicular to street) D = _______ feet
Building height (ground level to roof) H = _______ feet
Building size (L*D) A = _______ sq ft
Aspect ratio MAX(H/L,H/D) R = _______

Number of floors (ground floor and above) N = _______
Number of basements B = _______

1984 Replacement value $ __________

Amount of earthquake insurance $ __________

Underwriter's building classification ________
[ ] ISO
[ ] Other System: __________

SURVEY BUILDING CLASSIFICATION: __________

STRUCTURAL SYSTEM

GENERAL TYPE:

[ ] (1) Mobile Home
[ ] (1) Wood frame

[ ] (2) All metal

[ ] (3) Steel frame
- [ ] Simple
- [ ] Moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Ductile moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Poured-in-place concrete fire-proofing
- [ ] Shear walls

[ ] (4) Concrete frame
- [ ] Precast elements
- [ ] Moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Ductile moment resisting
  - [ ] One-way frame
  - [ ] Two-way frame
- [ ] Shear walls

[ ] (5) Mixed construction
- [ ] Unreinforced masonry
- [ ] Reinforced masonry
- [ ] Tilt-up

[ ] (6) Special earthquake resistant
(Requires written justification)

EMERGENCY SYSTEMS:

[ ] Fire alarms

[ ] Heat and/or smoke detectors

[ ] Fire doors
- [ ] Self closing
- [ ] Automatic closing (Fusable link)

EXTERIOR WALLS:

Location: ____________ story

Type: [ ] Bearing
[ ] Non-bearing
[ ] Curtain
[ ] Panel
[ ] In-filled

Material: [ ] Adobe
[ ] Wood
[ ] Cripple studs
[ ] Unbraced
[ ] Braced
[ ] Brick veneer
[ ] Stucco
[ ] Other Type: ____________________
[ ] Masonry
[ ] Hollow
[ ] Solid
[ ] Unreinforced
[ ] Reinforced
[ ] Brick
[ ] Tile
[ ] CMU
[ ] Concrete
[ ] Glass
[ ] Steel panels
[ ] Precast concrete panels
[ ] Other Type: ____________________

Percent of exterior wall openings: North ___________
East ___________
South ___________
West ___________

Thickness: ______ in

Through-wall ties: ____

INTERIOR WALLS:

Location: ____________ story

Shear Walls:

Type: [ ] None
[ ] Isolated
[ ] Core

Material: [ ] Masonry
[ ] Hollow

```
                  [ ] Solid
                  [ ] Unreinforced
                  [ ] Reinforced
                  [ ] Brick
                  [ ] Tile
                  [ ] CMU
              [ ] Concrete
              [ ] Other       Type: ________________

   Thickness: ______ in


 Partitions:

       Type: [ ] Non-moveable
             [ ] Moveable

   Material: [ ] Wood studs
                 [ ] Plaster
                 [ ] Gypsum board
                 [ ] Plywood panel
                 [ ] Other          Type: ________________
             [ ] Metal studs
                 [ ] Plaster
                 [ ] Gypsum board
                 [ ] Plywood panel
                 [ ] Other          Type: ________________
             [ ] Plaster
             [ ] Masonry
                 [ ] Brick
                 [ ] Tile
                 [ ] CMU
                 [ ] Non-reinforced
                 [ ] Reinforced

        Top: [ ] Below ceiling
             [ ] At ceiling
             [ ] At underside of upper floor/roof
                 Anchorage: [ ] None
                            [ ] Poor
                            [ ] Good
                            [ ] Excellent
  Thickness: ______ in
```

FLOOR FRAMING:

Location: ____________ story

Type: [ ] Concrete slab on grade
[ ] Joists
[ ] Wood
[ ] Steel
[ ] Concrete
[ ] Not anchored
[ ] Anchored
[ ] Beam/girder
[ ] Timber
[ ] Steel
[ ] Concrete
[ ] Wood trussed joists
[ ] Concrete slab
[ ] Poured-in-place
[ ] Precast
[ ] Reinforced
[ ] Prestressed
[ ] Solid
[ ] Hollow
[ ] Ribbed
[ ] Waffel
[ ] Flat slab
[ ] Slab w/drops
[ ] Slab w/capitals
[ ] Slab w/drops and capitals
[ ] Precast elements Type: ______________

Deck: [ ] Wood
[ ] Steel
[ ] Concrete planks
[ ] Light concrete deck slab (LEQ 3")
[ ] Heavy concrete deck slab (GTR 3")
[ ] Other Type: ______________________

Diaphragm: [ ] No
[ ] Poor
[ ] Good
[ ] Excellent

Diaphragm shear transfer connection: [ ] None
[ ] Poor
[ ] Good
[ ] Excellent

ROOF FRAMING:

Surface: [ ] Flat
[ ] Sloped
[ ] Curved

Type: [ ] Joists
- [ ] Wood
- [ ] Steel
- [ ] Concrete
- [ ] Not anchored
- [ ] Anchored

[ ] Beam/girder
- [ ] Timber
- [ ] Steel
- [ ] Concrete

[ ] Wood trussed rafters
[ ] Truss/purlin
- [ ] Timber
- [ ] Steel

[ ] Concrete slab
- [ ] Poured-in-place
- [ ] Precast
- [ ] Reinforced
- [ ] Prestressed
- [ ] Solid
- [ ] Hollow
- [ ] Ribbed
- [ ] Waffel
- [ ] Flat slab
- [ ] Slab w/drops
- [ ] Slab w/capitals
- [ ] Slab w/drops and capitals
- [ ] Precast elements Type: _____________

Deck: [ ] Wood
[ ] Steel
[ ] Concrete planks
[ ] Light concrete deck slab (LEQ 3")
[ ] Heavy concrete deck slab (GTR 3")
[ ] Other Type: ______________________

Diaphragm: [ ] No
[ ] Poor
[ ] Good
[ ] Excellent

Diaphragm shear transfer connection: [ ] None
[ ] Poor
[ ] Good
[ ] Excellent

ORNAMENTATION:

Exterior: Inadequately anchored ornamentation and/or veneer above the first story ____________
____
____

Stone coping on parapets, stone or pre-cast ledges, or sculptered sills and key-stones ________________________________
____
____

Interior: [ ] Suspended ceilings
- [ ] Tie wires
  - [ ] Not looped
  - [ ] Looped
- [ ] Lateral bracing
  - [ ] None
  - [ ] Wires
  - [ ] Metal channels

[ ] Suspended light fixtures
- [ ] Wire
- [ ] Chain
- [ ] Pendant (pipe / conduit)

[ ] Poorly anchored chandeliers and/or other ceiling appurtanacies

[ ] Drop-in fluorescent light fixtures

[ ] Bracket-mounted television sets _____
____

[ ] Floor coverings ____________________
____
____

MECHANICAL/ELECTRICAL:

Heating Equipment: _______________
Air Conditioning Equipment: _______________
Electrical Generation and Distribution Equipment: _______________
Elevators: _______________
Escalators: _______________
Miscellaneous Equipment: _______________

Anchorage: (All equipment) _________________________

UNUSUAL CONDITIONS:

Previous EQ damage: ______________________________

Settlement: (Differential settlement, cracking, bowing, leaning of walls) ______________________________
____
____

Shear walls: (Symmetric or non-symmetric) ____________

Lateral bracing: (Type) ______________________________
(Symmetric or non-symmetric) ____________

Building shape: [ ] Rectangular
[ ] Triangular/L-shape/T-shape/H-shape
[ ] "Open front" (U-shape)

Columns: (Continuous, non-continuous) ____________
____

Foundation: [ ] Above grade concrete piers or pedestals
[ ] Unreinforced
[ ] Reinforced
[ ] Above grade masonry piers or pedestals
[ ] Unreinforced
[ ] Reinforced
[ ] Tiedowns
[ ] Cross-bracing

Floors: (Cracking or sagging) ______________________________

Swimming Pools: (On roofs) ______________________________

Aspect ratio: R = ______

Other: ______________________________
____
____
____

HAZARDOUS EXPOSURES:

Roof tanks: Number: ____________________
Purpose: ____________________
Size: ____________________
Bracing/anchorage: ____________________

Roof signs: ______________________________

Parapet walls: [ ] None
[ ] Unreinforced masonry
[ ] Reinforced masonry
[ ] Other Type: ____________________

```
                      [ ] Unbraced
                      [ ] Braced

   Overhanging walls: _________________________________________

           Chimneys: Height above roof: _______________________
                              Material: _______________________
                      Anchorage/bracing: _______________________

           Pounding: _________________________________________

         FOUNDATION:

               Type: [ ] Strip footings
                     [ ] Isolated footings
                     [ ] Mat foundation
                     [ ] Piles
                         [ ] Wood
                         [ ] Steel
                         [ ] Concrete
                     [ ] Caissons
                     [ ] Other   Type: ________________________


SOIL TYPE/CONDITION: [ ] Rock or firm alluvium or well-
                         engineered man-made fill
                     [ ] Soft alluvium
                     [ ] Poor (natural or man-made)
                         Remarks: _____________________________
                                  _____________________________
```

CRITICAL FACILITIES
BUILDING STRUCTURE EARTHQUAKE VULNERABILITY RATING FORM

BUILDING: ______________________________ CLASS PML = ______

MODIFICATION FACTOR = [1.0 + (SUM OF MODIFIERS)/100] . . . ______

BUILDING PML = (CLASS PML)*(MODIFICATION FACTOR) . . . . . ______

MODIFIERS:

1. Occupancy type . . . . ______

(1) Office, Habitational, Hospital, Laboratory, School
[ ] (-5) Low damageability
[ ] (0) Average damageability
[ ] (+5) High damageability

(2) Mercantile, Restaurant, Church
[ ] (-10)
[ ] (-5)
[ ] (0)

(3) Manufacturing, Warehousing, Parking structure, Stadium
[ ] (-15)
[ ] (-10)
[ ] (0)

2. Walls. . . . . ______

A. Exterior walls

(1) Concrete, poured or precast
(2) Masonry, reinforced solid or hollow
(3) Metal
(4) Glass
(5) Stucco on studs
[ ] (-5)
[ ] (0)
[ ] (+5)
(6) Masonry, unreinforced solid
[ ] (0)
[ ] (+5)
[ ] (+10)
(7) Masonry, unreinforced hollow
[ ] (0)
[ ] (+10)
[ ] (+20)

B. Interior walls and partitions

(1) Concrete, poured or precast
(2) Masonry, reinforced solid or hollow
(3) Plaster or gypsumboard on metal or wood studs
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Masonry, unreinforced solid or hollow
(5) Tile, hollow clay
[ ] (0)
[ ] (+5)
[ ] (+10)

3. Diaphragms . . . . ______

A. Floors

(1) Concrete, poured
(2) Metal deck with concrete fill
(3) Metal
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Concrete, precast
(5) Wood: maximum ratio LEQ 2:1 w/ length LEQ 150'
[ ] (0)
[ ] (+5)
[ ] (+10)
(6) Wood: maximum ratio GTR 2:1
[ ] (0)
[ ] (+10)
[ ] (+20)

B. Roof (Null modifier when building GTR 5 stories)

(1) Concrete, poured
(2) Metal deck with concrete fill
(3) Metal
[ ] (-5)
[ ] (0)
[ ] (+5)
(4) Concrete, precast
(5) Wood or gypsum: maximum ratio LEQ 2:1 w/ length LEQ 150'
[ ] (0)
[ ] (+5)
[ ] (+10)
(6) Wood or gypsum: maximum ratio GTR 2:1
[ ] (0)
[ ] (+10)
[ ] (+20)

C. Purlin anchors lacking (+10)

```
4. Ornamentation. . . . . . . . . . . . . . . . . ______

   A. Exterior
         [ ] (     -5)
         [ ] (      0)
         [ ] ( +5,+10)

   B. Interior (includes ceilings and floor covers)
         [ ] (     -5)
         [ ] (      0)
         [ ] ( +5,+10)

5. Mechanical and Electrical Systems. . . . . . . ______

         [ ] (-10, -5)
         [ ] (      0)
         [ ] ( +5,+10)

6. Unusual Conditions . . . . . . . . . . . . . . ______

         Include previous earthquake damage and repairs

         [ ] (-10, -5)
         [ ] (     +5)
         [ ] (+10,+25)

7. Hazardous exposures  . . . . . . . . . . . . . ______

      "Average" means "No exposure"

   A. Roof tanks
         [ ] Null
         [ ] (      0)
         [ ] (    +25)

   B. Roof signs and overhanging walls
         [ ] Null
         [ ] (      0)
         [ ] ( +5,+10)

   C. Founding of adjacent buildings
         [ ] Null
         [ ] (      0)
         [ ] (     +5)

8. Site dependent hazards . . . . . . . . . . . . ______

   A. Foundation materials
         [ ] (  0)  Rock or firm alluvium or
                    well-engineered man-made
                    fill
         [ ] (+10)  Soft alluvium
         [ ] (+25)  Poor (natural or man-made)

                                SUM OF MODIFIERS: ______
```

PRELIMINARY SCREENING
(PRE INSPECTION DATA)

BUILDING NO. 55 INSPECTED BY SAF DATE 1/15/86

DESCRIPTIVE TITLE (Current Use) HOSPITAL BUILDING

CLASSIFICATION ESSENTIAL

AVAILABILITY OF DESIGN DATA DRAWINGS AND CALCULATIONS ARE AVAILABLE

BUILDING DATA:

Number of Stories 3

Height 35' Plan (Show Dimensions) 48' x 192'

CONSTRUCTION:

Structural System Structural Steel Frame

Roof METAL DECK WITH LIGHTWEIGHT FILL

Intermediate Floors METAL DECK WITH CONC. FILL

Ground Floors SLAB ON GRADE

Foundations

Interior Walls

Exterior Walls

LATERAL FORCE RESISTING SYSTEM DMRSF TRANSV. BRACED FRAME LONGIT.

EVALUATION:

General Condition

Earthquake Damage Potential

DAMAGE OBSERVED:

COMMENTS:

APPENDIX B

DETERMINATION OF BASIC STRUCTURAL HAZARD SCORES AND MODIFIERS

This Appendix presents the derivation of the Basic Structural Hazard score and discusses modifications to account for building specific problems and to extend this score to areas outside of California. Sample calculations of probabilities of damage and resulting Basic Structural Hazard scores are included for several building types. A summary of Basic Structural Hazard scores for all structural types and for all regions is found in Table B1.

B.1 Determination of Structural Score S

The Basic Structural Hazard (BSH) is defined for a type or class of building as the negative of the logarithm (base 10) of the probability of damage (D) exceeding 60 percent of building value for a specified NEHRP Effective Peak Acceleration (EPA) loading (reflecting seismic hazard) as:

$$BSH = -\log_{10} [Pr(D \geq 60\%)] \qquad (B1a)$$

The BSH is a generic score for a type or class of building, and is modified for a specific building by Performance Modification Factors (PMFs) specific to that building, to arrive at a Structural Score, S. That is,

$$BSH \pm PMF = S \qquad (B1b)$$

where the

$$\text{Structural Score } S = \log_{10} [Pr\,(D \geq 60\%)] \qquad (B1c)$$

is the measure of the probability or likelihood of damage being greater than 60 percent of building value for the *specific* building.

Sixty percent damage was selected as the generally accepted threshold of major damage, the point at about which many structures are demolished rather than repaired (i.e., structures damaged to 60 percent of their value are often a "total loss"), and the approximate lower bound at which there begins to be a significant potential for building collapse (and hence a significant life safety threat). Value is used as defined in ATC-13 (ATC, 1985), which may be taken to mean replacement value for the building.

The determination of the probability of damage exceeding 60 percent for a class of buildings or structures for a given ground motion defined in terms of Modified Mercalli Intensity (MMI), Peak Ground Acceleration (PGA) or Effective Peak Ground Acceleration is a difficult task for which insufficient data or methods presently exist. In order to fill this gap, earthquake engineering expert opinion was elicited in a structured manner in the ATC-13 project, as to the likelihood of various levels of damage given a specified level of ground motion (ATC, 1985).

The Basic Structural Hazard scores herein were developed from earthquake damage related information, using damage factors (DF) from ATC-13 (ATC, 1985), wherein damage factor is defined as the ratio of dollar loss to replacement value. It is assumed in ATC-13 that, depending on the building class, both modern code and older non-code buildings may be included, and that the damage data are applicable to buildings throughout the state of California. Inasmuch as ATC-13 was intended for large scale economic studies and not for studies of individual structures, damage factors apply to "average" buildings in each class. ATC-13 damage factors were chosen as the

Table B1: Basic Structural Hazard Scores for all Building Classes and NEHRP Areas

	Building Identifier	Seismic Area (NEHRP MAP AREAS) low (1,2)	moderate (3,4)	high (5,6,7)
W	WOOD FRAME	8.5	6.0	4.5
S1	STEEL MRF	3.5	4.0	4.5
S2	BRACED STEEL FRAME	2.5	3.0	3.0
S3	LIGHT METAL	6.5	6.0	5.5
S4	STEEL FRAME W/CONCRETE SW	4.5	4.0	3.5
C1	RC MRF	4.0	3.0	2.0
C2	RCSW NO MRF	4.0	3.5	3.0
C3/S5	URM INFILL	3.0	2.0	1.5
PC1	TILT-UP	3.5	3.5	2.0
PC2	PC FRAME	2.5	2.0	1.5
RM	REINFORCED MASONRY	4.0	3.5	3.0
URM	UNREINFORCED MASONRY	2.5	2.0	1.0

basis for the handbook scores because, at the present time, this is the most complete and systematically compiled source of earthquake damage related information available. Appendix G of ATC-13 contains summaries of experts' opinions of DFs for 78 facility classes (designed in California) due to 6 different levels of input motion. Each ATC-13 expert was asked to provide a low, best and high estimate of the damage factor at Modified Mercalli Intensities VI through XII. The low and high estimates were defined to be the 90% probability bounds of the damage factor distribution. The best estimate was defined for the experts as the DF most likely to be observed for a given MMI and facility class (Appendix E and equation 7.10, ATC-13). This relationship is illustrated in Figure B1.

To incorporate the inherent variability in structural response due to earthquake input and variations in building design and construction, the DF is treated as a random variable—that is, it is recognized that there is uncertainty in the DF, for a given ground motion. This uncertainty is due to a number of factors including variation of structural properties within the category of structure under consideration and variation in ground motion. In ATC-13, DF uncertainty about the mean was examined and found to be acceptably modeled by a Beta distribution although differences between the Beta, lognormal and normal probabilities were very small (see for example ATC-13, Fig. 7.9). For convenience herein, the lognormal rather than Beta distribution was chosen to represent the DF. The lognormal distribution offers the advantage of easier calculation using well-known polynomial approximations. Ideally a truncated lognormal distribution should be used to account for the fact that the DF can be no larger than 100. In the worst case this would have only changed the resulting hazard score by 5%. It should be noted that the lognormal distribution was the ATC-21 subcontractor's preference, and the Beta or other probability distributions could be used in developing structural scores.

For specified building classes (as defined in ATC-13) and for load levels ranging from MMI VI to XII, parameters of damage probability distributions were estimated from the "weighted statistics of the damage factor" given in Appendix G of ATC-13. Weights based on experience level and confidence of the experts were factored into the mean values of the low, best and high estimates (ML, MB, MH) found in that Appendix. For the development of hazard scores, the mean low and mean high estimates of the DF were taken as the 90% probability bounds on the damage factor distribution. The mean best estimate was interpreted as the median DF. Major damage was defined as a DF > .60 (greater than 60 percent damage).

For any lognormally distributed random variable, X, a related random variable, Y=ln(X), is normally distributed. The normal distribution is characterized by two parameters, its mean and standard deviation. The mean value of the normal distribution, m, can be equated to the median value of the lognormal distribution, x_m, by

$$m = \ln(x_m) \qquad \text{(B2)}$$

(Ang and Tang, 1975). Thus if it is assumed that the DF is lognormally distributed with the median = MB, the ln(DF) is normally distributed with mean m=ln(MB). The additional information needed to find the standard deviation, s, is provided by knowing that 90% of the probability distribution lies between ML and MH. Thus approximately 95% of the distribution is below the MH damage factor. From tables of the cumulative standard normal distribution, F(x), where x is the standard normal variate defined by $x=(y-m)/s$, it can be seen that F(x=1.64)=0.95. Therefore $(y-m)/s = 1.64$, where in this case y=ln(MH). The standard deviation may then be calculated from $s = (\ln(MH)-m)/1.64$. A similar calculation could be performed using the ML and the 5% cutoff. An average of these two values results in the following equation:

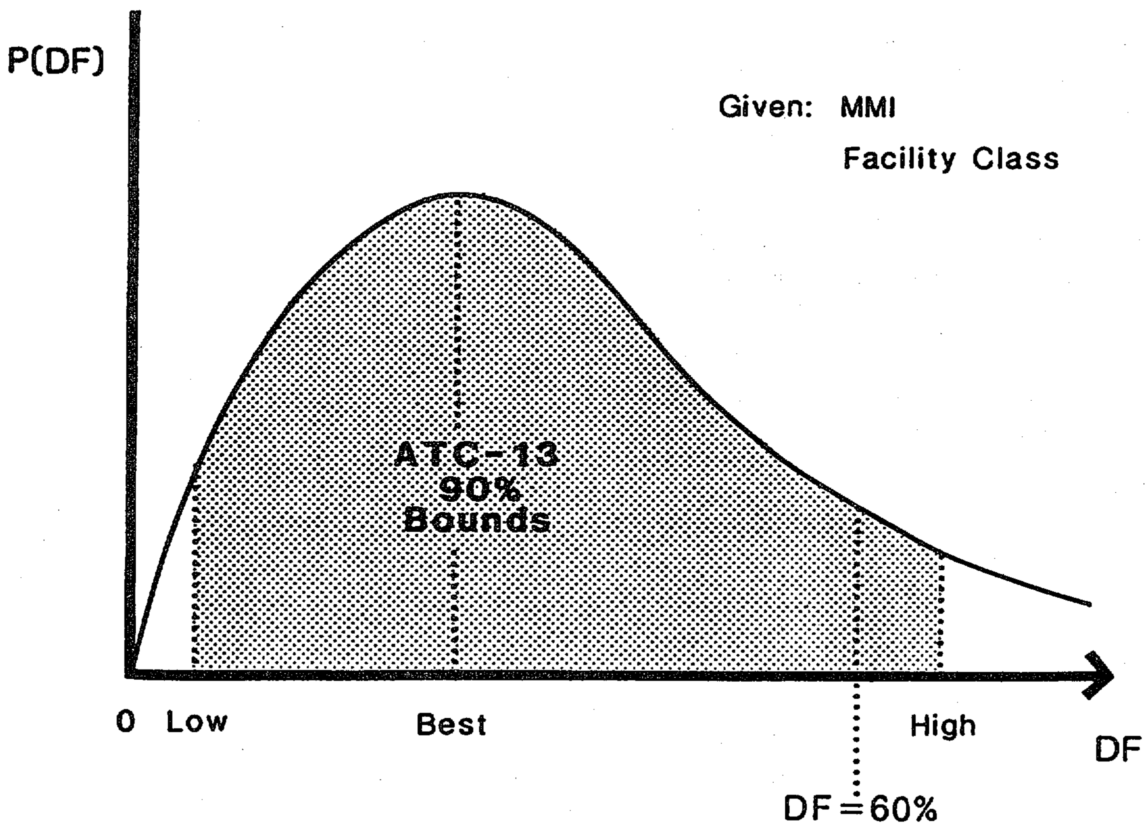

P(DF)
Given: MMI
Facility Class
ATC-13
90%
Bounds
0
Low
Best
High
DF
DF = 60%

Figure B1

$$s = (\ln(MH)-\ln(ML))/3.28 \qquad (B3)$$

A FORTRAN program was used to calculate the parameters m and s for various ATC-13 facility classes and all MMI levels.

To estimate probabilities of exceeding a 60% DF for various NEHRP areas, MMI was converted to EPA according to:

$$PGA = 10^{(MMI-1)/3} \qquad (B4)$$

where PGA is in gals (cm/sec^2), and

$$EPA = .75\ PGA \qquad (B5)$$

Equation B4 is a modification of the standard conversion given in Richter (1958) to arrive at PGA at the mid-point of the MMI value (rather than at the threshold, as given by Richter). Equation B5 is an approximate conversion (N. C. Donovan, personal communication). Only MMI VI to IX were considered, as this is the equivalent range of EPA under consideration in NEHRP Areas 1 to 7.

It was found that large uncertainty in DF for MMI VI and sometimes VII could lead to inconsistencies in the calculated probabilities of damage. To smooth these inconsistencies, $\log_{10}(s)$ was regressed against $\log_{10}$(EPA). The standard deviations of the damage probability distributions for various EPA levels were calculated from the resulting regression.

Once the parameters of the normal distribution were found, the probability of the DF being greater than 60%, Q, was calculated from the following polynomial approximation of the normal distribution (NBS 55, 1964). For the derivation of structural hazard scores, the standard variate $x = (\ln(60)-m)/s$:

$$Q(x) = Z(x)[b_1t+b_2t^2+b_3t^3+b_4t^4+b_5t^5] \qquad (B6)$$

where

$$Z(x) = (2\pi)^{-.5}*\exp(-x^2/2) \quad \text{and} \quad t = 1/(1+px)$$

and the constants are

$b_1 = .319381530$	$b_2 = -.356563782$
$b_3 = 1.781477937$	$b_4 = -1.821255978$
$b_5 = 1.330274429$	$p = .2316419$

The resulting values of $\log_{10}(Q)$ (i.e. $\log_{10}[Pr(D >= 60\%)]$) corresponded to initial values of the Basic Structural Hazard score defined in Equation B1. These Structural Hazard scores are presented in Table B2 under NEHRP Map Area 7. These scores for the ATC-13 building classification were then used to determine the scores for the building classifications of ATC-14 (ATC, 1987), which are also employed here in ATC-21 (see left column, Table B1). In many cases, the correspondence of ATC-13 and ATC-14 is one-to-one (e.g., light metal). In some cases, several building types of ATC-13 correspond to one in ATC-14, and were therefore averaged to determine the ATC-21 score. In a few instances, due to inconsistencies still remaining despite the smoothing discussed above, these initial Basic Structural Hazard scores were adjusted on the basis of judgment, by consensus of the Project Engineering Panel. In order to extend the Structural Hazard scores for buildings constructed according to California building practices (which was all that ATC-13 considered) to other NEHRP Map Areas, two factors must be incorporated in the determination of the Structural Hazard score:

1. The seismic environment (i.e., lower EPA values) for NEHRP Map Areas 1 through 6 must be considered.
2. Buildings constructed in places other than the high seismicity portions of California, which probably have not been designed for the same seismic loadings and with the same seismic detailing as in California, must be considered. This latter aspect is termed the "non-California building" factor.

Table B2: Structural Hazard Score Values After Modification for Non-California Buildings (prior to rounding)
(Follows ATC-13 (ATC, 1985) building classifications)

EPA (g)	.05	.05	.10	.15	.20	.30	.40	LOW	MOD	HIGH
NEHRP Area	1	2	3	4	5	6	7	1,2	3,4	5,6,7
WOOD FRAME -LR	8.3	8.3	6.5	5.6	5.3	4.7	4.0	8.5	6.0	4.5
LIGHT METAL	6.6	6.6	6.4	5.8	5.5	5.3	5.7	6.5	6.0	5.5
URM - LR	3.1	3.1	2.0	2.0	1.7	1.4	1.2	3.0	2.0	1.5
URM - MR	2.5	2.5	1.9	1.5	1.3	1.1	1.0	2.5	1.5	1.0
TILT UP	4.8	4.8	4.9	3.1	2.9	1.9	2.4	5.0	3.5	2.0
BR STL FRAME - LR	3.2	3.2	3.7	3.1	3.4	3.0	3.1	3.0	3.5	3.0
BR STL FRAME - MR	2.1	2.1	2.7	2.3	2.8	2.6	2.9	2.0	2.5	3.0
BR STL FRAME - HR	2.3	2.3	2.6	1.9	2.3	1.9	2.0	2.5	2.5	2.0
STL PERIM. MRF - LR	4.3	4.3	5.4	4.7	4.9	5.5	5.4	4.5	5.0	5.5
STL PERIM. MRF - MR	3.7	3.7	4.5	3.7	3.8	4.1	3.9	3.5	4.0	4.0
STL PERIM. MRF - HR	3.6	3.6	3.5	2.7	2.6	2.7	2.4	3.5	3.0	2.5
STL DISTRIB MRF - LR	3.1	3.1	3.8	3.5	3.8	4.4	4.5	3.0	3.5	4.5
STL DISTRIB MRF - MR	3.0	3.0	3.8	3.3	3.5	3.8	3.7	3.0	3.5	4.0
STL DISTRIB MRF - HR	3.0	3.0	3.4	2.8	2.8	2.8	2.5	3.0	3.0	2.5
RCSW NO MRF - LR	5.4	5.4	5.4	3.9	4.6	4.0	3.5	5.5	4.5	4.0
RCSW NO MRF - MR	4.6	4.6	4.1	2.7	3.4	2.9	2.5	4.5	3.5	2.5
RCSW NO MRF - HR	3.5	3.5	3.2	2.1	2.5	2.1	1.8	3.5	2.5	2.0
URM INFILL - LR	2.8	2.8	2.1	1.6	1.3	1.2	1.1	3.0	1.5	1.0
URM INFILL - MR	2.5	2.5	1.7	1.2	1.1	1.1	1.1	2.5	1.5	1.0
URM INFILL - HR	2.3	2.3	1.5	1.1	1.0	1.0	1.1	2.5	1.0	1.0
ND RC MRF - LR	4.2	4.2	4.2	2.4	2.9	2.7	2.2	4.0	3.0	2.5
ND RC MRF - MR	3.9	3.9	3.7	2.3	2.2	2.0	1.7	4.0	2.5	2.0
ND RC MRF - HR	3.4	3.4	3.5	2.1	2.2	2.1	1.8	3.5	2.5	2.0
D RC MRF - LR	7.6	7.6	8.7	6.6	7.0	6.5	5.7	7.5	7.5	6.0
D RC MRF - MR	5.0	5.0	6.3	4.8	5.4	5.4	4.9	5.0	5.5	5.0
D RC MRF - HR	5.7	5.7	5.9	4.0	4.3	3.8	3.2	5.5	4.5	3.5
PC FRAME - LR	3.0	3.0	3.8	2.3	2.0	1.4	1.6	3.0	2.5	1.5
PC FRAME - MR	1.8	1.8	2.2	1.7	2.2	1.8	1.2	2.0	2.0	1.5
PC FRAME - HR	1.6	1.6	2.3	1.4	1.7	1.4	1.0	1.5	2.0	1.0
RM SW W/O MRF - LR	3.9	3.9	5.4	4.5	4.1	3.5	2.9	4.0	4.5	3.0
RM SW W/O MRF - MR	3.4	3.4	4.3	3.4	3.1	2.6	2.2	3.5	3.5	2.5
RM SW W/O MRF - HR	2.7	2.7	3.4	2.6	2.3	1.9	1.7	2.5	3.0	2.0
RM SW W/ MRF - LR	4.0	4.0	5.8	5.0	4.7	4.1	3.6	4.0	5.0	4.0
RM SW W/ MRF - MR	5.7	5.7	7.6	5.8	5.1	3.9	3.1	5.5	6.0	3.5
RM SW W/ MRF - HR	5.9	5.9	8.1	6.2	5.5	4.3	3.4	6.0	6.5	4.0
LONG SPAN	4.2	4.2	3.9	3.2	3.3	3.5	3.2	4.0	3.5	3.5

With regard to the first of these factors, to facilitate calculating the final Structural Hazard scores for the EPA loadings in NEHRP Areas 1 through 6, $\log_{10}[\log_{10}(\text{Structural Hazard Score})]$ was regressed against EPA and scores were calculated from the resulting regression. These values represent the values for a "California building" (i.e., designed and built according to standard California seismic practices) in a different NEHRP Map Area. The extension of the scoring system to structures outside of California (i.e., "non-California buildings") is discussed below.

B.2 Extension to Non-California Building Construction

Due to the nature of data compiled in ATC-13, the above Structural Hazard scores are appropriate for "average" buildings designed and built in California, subjected to seismic loadings appropriate for NEHRP Map Area 7. In regions where building practices differ significantly from California (i.e., NEHRP Map Area 7) building practices, the Structural Hazard score should be modified. It would be expected that in regions where seismic loading does not control the design, this would lead to an increase in the value of the Structural Hazard score.

An example of this "non-California building" effect might be a reinforced masonry (RM) building in NEHRP Map Area 3, where local building codes typically may not have required any design for seismic loading until recently, if at all. This is not to say that buildings in NEHRP Map Area have no lateral load (and hence seismic) capacity. Design for wind loads would provide some lateral load capacity, although lack of special details might result in relatively little ductility. However, interior masonry partitions (e.g., interior walls built of concrete masonry units, CMU) might typically be unreinforced, with ungrouted cells, for example. Although the building structure could thus be fairly classified as RM, failure and probable collapse of most of the interior walls would be a major life-safety hazard, as well as resulting in major property damage. Although the exterior walls are reinforced, they will likely lack details required in UBC Seismic Zones 3 and 4, and thus will likely have less ductility. Therefore, the Structural Hazard score in NEHRP Map Area 3 for this building type should be lower than it would be for a "California" building, if the seismic loading were the same. Given that the seismic loading in NEHRP Map Area 3 is less than in most of California, the actual resulting score may be higher or lower, depending on the seismic capacity/demand ratio.

Some building types, on the other hand, such as older unreinforced masonry (URM) may be no different in California than in most other parts of the United States, so that the seismic capacity is the same in many NEHRP areas. Since the seismic loading is less for most non-California map areas (e.g., NEHRP Map Areas 1, 2, 3), the seismic capacity/demand ratio increases for these type of buildings for NEHRP Map Areas 1, 2, 3. Similarly, building types whose seismic capacity is the same will have higher Basic Structural Hazard scores in the lower seismicity NEHRP Map Areas.

Quantification of the change in Structural Hazard score due to variations in regional seismicity can be treated in a rather straightforward manner, as outlined above. Changes in the Structural Hazard score due to variations in local design or building practices, as discussed above, however, is difficult because seismic experience for these regions is less, and expert opinion data similar to ATC-13 did not exist for non-California buildings. In the course of the development of the *ATC-21 Handbook* therefore, expert opinion was sought in order to extend the ATC-13 information to non-California building construction. Information was sought in a structured manner from experienced engineers in NEHRP Areas 1 to 6, asking them to compare the performance of specific building types in their regions to

California-designed buildings of the same type. After reviewing and comparing the responses, a composite of all responses for a region was sent to the experts, who were then asked, based on these composite results, for their final estimate of the seismic performance for each building type for their region.

Generally, for the same level of loading, the experts expected higher damage for buildings in their regions than for similar structures built in California, as might be expected. For a given NEHRP Map Area, although there was substantial scatter in these experts' responses, in most cases the responses could be interpreted such that the non-California building DF could be considered to differ by a constant multiple from the corresponding "California building" DF. That is, responses from all experts in each region were averaged and used to estimate the modification constant for each building type.

These modification constants (MC), presented in Table B3, were used to change the value of the mean best estimate from ATC-13 (MB) to a best estimate for each NEHRP Map Area (BENA) according to the following equation:

$$BENA = MC*MB \qquad (B7)$$

Keeping the standard deviation constant (as calculated in equation B3) and using the best estimate of the DF (BENA) from equation B7, Structural Hazard scores were calculated for each region using the methodology described in Section B.1. These structural scores are presented in Table B2, for each NEHRP Map Area.

Because the derived scores were based on expert opinion, and involved several approximations as discussed above, it was felt that the precision inherent in the Structural Hazard scores only warranted expressing these values to the nearest 0.5 (i.e., all were rounded to the nearest one half: .3 rounded to .5, 1.2 to 1.0 and so on). A comparison of scores for low rise (1 to 3 stories) and medium rise (4 to 7 stories) structures after rounding showed little or no difference for most building classes. Therefore, these values (before rounding) were averaged for low- and medium-rise buildings. This value, appropriate for low- and medium-rise buildings, is designated as the Basic Structural Hazard score. For high-rise construction (8+ stories), this is modified by a high-rise Performance Modification Factor (PMF). This high-rise PMF is a function of building class and was calculated by subtracting the Basic Structural Hazard score for low- and mid-rise buildings from that determined for high-rise buildings.

Lastly, a comparison of scores for different NEHRP Map Areas revealed very little difference of Structural Hazard scores for certain levels of seismicity. The scoring process was therefore simplified by grouping high, moderate, and low seismicity NEHRP areas together as follows:

Seismicity	NEHRP Areas
High	5, 6, 7
Moderate	3, 4
Low	1, 2

B.3 Sample Calculation of Basic Structural Hazard Scores

A sample calculation is presented here for ATC-13 facility class 1 (wood frame), based on data taken from Appendix G in ATC-13 (ATC, 1985), shown in Table B4. Although ATC-13 provided data for MMI VI to XII, the data for MMI greater than X do not correspond to the NEHRP Map effective peak accelerations. Therefore they were not included in developing the scores for this Rapid Screening Procedure (RSP).

Table B3: ATC-21 Round 2 Damage Factor Modification Constants

Structure Type	NEHRP Map Area				
	1,2	3	4	5	6
Wood Frame	1.0	1.3	1.3	1.2	1.0
Steel Moment Resisting Frame (S1)	1.9	1.2	1.4	1.3	1.0
Steel Frame with Steel Bracing or Concrete Shear Walls	1.9	1.2	1.4	1.1	1.1
Light Metal	1.1	1.1	1.3	1.3	1.2
Steel Frame or Concrete Frame with Unreinforced Masonry Infill Walls	1.2	1.2	1.3	1.3	1.2
Concrete Moment Resisting Frame	2.2	1.3	1.5	1.2	1.0
Concrete Shear Wall	1.7	1.3	1.5	1.1	1.0
Tilt-up (PC1)	2.0	1.2	1.5	1.3	1.4
Precast Concrete Frames	2.9	1.1	1.8	1.2	1.3
Reinforced Masonry (RM)	2.9	1.1	1.3	1.1	1.0
Unreinforced Masonry	1.1	1.2	1.0	1.0	1.0

The mean and standard deviation of the Normal distribution are calculated from equations B2 and B3 with the results shown in Table B5.

A regression of $\log_{10}(s)$ versus $\log_{10}(\text{EPA})$ yields the following equation:

$$\log_{10}(s) = -0.409 - 0.192*\log_{10}(\text{EPA})$$

Using values of s obtained from the above equation and the polynomial approximation of the normal distribution given in Equation B6, probabilities of exceeding 60 percent damage were calculated for EPA values of .35 and lower. The resulting probabilities and hazard scores are shown in Table B6.

Finally $\log_{10}[\log_{10}(\text{BSH})]$ was regressed against EPA resulting in the following equation:

$$\log_{10}[\log_{10}(\text{BSH})] = -0.0101 - 0.532*\text{EPA}$$

Values of the Basic Structural Hazard score for California buildings calculated from the above equation for specified EPA are shown below:

EPA(g)	BSH
0.05	8.30
0.10	7.32
0.15	6.50
0.20	5.82
0.30	4.75
0.40	3.97

BSH = 3.97 corresponding to an EPA of 0.4g is the score for NEHRP Map Area 7. To calculate BSH for other NEHRP Map Areas the same process must be used with the modified mean damage factor described in Section B.2. For wood-frame structures the modification constants developed from the questionnaires are:

NEHRP Map Area	1	2	3	4	5	6
Modification Constant	1	1	1.3	1.3	1.2	1

Using these constants, the modified median damage factors for NEHRP Map Area 3, for example, are (see Equation B7):

MMI	VI	VII	VIII	IX
Median DF	1.0	1.9	5.9	11.5

Repeating the same procedure using the natural log of these median DF to calculate the mean of the normal distribution and the same standard deviations shown above, the Structural Hazard score is calculated for each NEHRP Map Area. The final values for the example given here (wood-frame buildings), before and after rounding to the nearest half, are shown in Table B7 for this example of wood buildings and in Table B2 for all building types.

Finally, because there appeared to be little variation between some NEHRP Map Areas, these were grouped together into three areas, with corresponding BSH values (see Table B1). For the example of wood-frame buildings, resulting values are:

	NEHRP Map Areas	BSH
LOW	1, 2	8.5
MODERATE	3, 4	6.0
HIGH	5, 6, 7	4.5

Table B4

MMI	PGA (g)	EPA (g)	Damage Factor (%) Mean Low (ML)	Mean Best (MB)	Mean High (MH)
VI	0.05	0.04	0.2	0.8	2.6
VII	0.10	0.08	0.7	1.5	4.8
VIII	0.22	0.16	1.8	4.7	11.0
IX	0.47	0.35	4.5	9.2	19.7

Table B5

EPA (g)	ln (ML)	ln (MH)	*s* (std. dev.)	*m* (mean=ln{MB})
0.04	-1.609	0.956	0.782	-0.223
0.08	-0.356	1.569	0.587	0.405
0.16	0.588	2.398	0.552	1.548
0.35	1.504	2.981	0.450	2.219

Table B6

EPA	$Pr(D \geq 60)$	BSH
0.04	2.69×10^{-9}	8.57
0.08	3.80×10^{-9}	8.42
0.16	1.91×10^{-6}	5.72
0.35	4.07×10^{-5}	4.39

Table B7

NEHRP	EPA (g)	Final Values	BSH
1	0.05	8.3	8.5
2	0.05	8.3	8.5
3	0.10	6.45	6.50
4	0.15	5.6	5.5
5	0.20	5.26	5.5
6	0.30	4.75	5.0
7	0.40	3.97	4.0

The final resulting values of Basic Structural Hazard score presented in Table B1 are intended for use nationwide. However, local building officials may feel that building practice in their community differs significantly from the conditions typified by the Modification Constants (MCs) in Table B3. The computer source code and data employed for this study is therefore furnished (Figure B2) so that alternative MCs may be employed to generate BSH scores based on an alternative set of MCs. An alternative computation might be conducted, for example, if a community in NEHRP Map Area 5 (e.g., Memphis, TN) felt that the MCs for Map Area 4 were more appropriate. Example resulting BSH scores would then be:

Wood	5.0
Light Metal	5.5
URM	1.5
Tilt-up	2.5

Note that if non-standard BSH scores are thus computed, PMFs should be reevaluated. In most cases, however, the BSH scores in Table B1 should be appropriate.

The interpretation of these values is rather straightforward—a value of 8.5 in Low seismicity areas indicates that on average wood-frame buildings, when subjected to EPA of 0.05g, have a probability of sustaining major damage (i.e., damage greater than 60 percent of their replacement value) of $10^{-8.5}$. In High seismicity areas, where the EPA is 0.3g to 0.4g, the probability of sustaining major damage is $10^{-4.5}$.

Thus, BSH has a straightforward interpretation: if BSH is 1, the probability of major damage is 1 in 10, if BSH is 2, the probability of major damage is 1 in 100, if BSH is 3, the probability of major damage is 1 in 1000, and so on.

It should be noted that BSH as defined and used here is similar to the structural reliability index, Beta (Hasofer and Lind, 1974), which can be thought of as the standard variate of the probability of failure (if the basic variables are normally distributed, which is often a good approximation). For values of BSH between about 0 and 5 (typically the range of interest herein), Beta and BSH are approximately equal. Further, it should be noted that research into the Beta values inherent in present building codes (NBS 577, 1980) indicates that Beta (or BSH) values of 3 for gravity loads and about 1.75 for earthquake loads are typical.

B.4 Performance Modification Factors

There are a number of factors that can modify the seismic performance of a structure causing the performance of an individual building to differ from the average. These factors basically are related to significant deviations from the normal structural practice or conditions, or have to do with the effects of soil amplification on the expected ground motion.

Deviations from the normal structural practice or conditions, in the case of wood frame buildings for example, can include deterioration of the basic wood material, due to pests (e.g., termites) or rot, or basic structural layout, such as unbraced cripple walls or lack of bolting of the wood structure to the foundation. The number and variety of such performance modification factors, for all types of buildings, is very large, and many of these cannot be detected from the street on the basis of a rapid visual inspection. Because of this, based on querying of experts and checklists from ATC-14, a limited number of the most significant factors were identified. Factors considered for this RSP were limited to those having an especially severe impact on seismic performance. Those that could not be readily observed from the street were eliminated. The performance modification factors were assigned values, based on judgment, such that when

```
C THIS PROGRAM FINDS THE STRUCTURAL SCORES FOR THE ATC21 HANDBOOK
C USING DATA FROM ATC13
C A LOGNORMAL DISTRIBUTION FOR DAMAGE IS ASSUMED
C T. Anagnos and C. Scawthorn 1987,1988
C---------------------------------------------------
C
C
      dimension x(10),y(10),epa(7)
      open(5,file='atcs.dat',status='old')
      open(6,file='outputcs',status='old')
      data epa /.05,.05,.1,.15,.2,.3,.4/
      write(6,200) (epa(i),i=1,7)
      write(6,210) (i,i=1,7)
200   format('EPA',17x,7(f5.2),'    LOW  MOD  HIGH       M2
H2')
 210   format('NEHRP Area          ',7(i5))
 202      FORMAT (' ')
          WRITE (6,202)
       read(5,*) ntype
       do 1 i=1,ntype
           call dfread
 1     continue
       end
c--------------------------------------------------
subroutine dfread
dimension pga(7),s(7),p(7),stvar(7),sigma(7),x(7),y(7)
DIMENSION dmodfy(7),dbest(7),sfinal(7), bldg(10)
       real lnlow(7),lnbest(7),lnhigh(7),epa(10)
       read(5,100) (bldg(i),i=1,6)
100    format(6a4)
c READ MODIFICATION FACTORS FOR EACH NEHRP AREA
       read(5,*) (dmodfy(j),j=1,7)
C CONVERT MMI TO PGA
       do 2 i=1,7
         read(5,*) xmmi,dlow,dbest(i),dhigh
         pga(i)=10**(((xmmi+0.5)/3.)-0.5)/981.
         lnlow(i)=alog(dlow)
       lnhigh(i)=alog(dhigh)
 2     continue
       do 50 nehrp=1,7
       do 7 i=1,7
       temp=dbest(i)/dmodfy(nehrp)
       if (temp.gt.100.) temp=100.
         lnbest(i)=alog(temp)
         x(i)=alog10(pga(i))
 7     continue
       do 3 i=1,7
 3     continue
 201   format(' ',4(f10.5,1x))
C COMPUTE STANDARD DEVIATION OF THE LOGNORMAL DISTRIBUTION
       do 4 i=1,7
         sigma(i)=(lnhigh(i)-lnlow(i))/3.28
         y(i)=alog10(sigma(i))
 4     continue
```

Figure B2

FORTRAN PROGRAM NEHRP.FOR
PAGE 2

```
C REGRESS LOG(SIGMA) AGAINST LOG(PGA)
      n=7
      call regres(x,y,n,a,b)
 202  format(' a=',f8.3,'b= ',f8.3)
C COMPUTE PROBABILITIES OF EXCEEDANCE USING AN APPROXIMATION
C OF THE LOGNORMAL DISTRIBUTION
C STVAR = STANDARD VARIATE
      c1=.31938153
      c2=-.356563782
      c3=1.781477937
      c4=-1.821255978
      c5=1.330274429
      do 5 i=1,7
      stvar(i)=(alog(60.)-lnbest(i))/10**(a+b*x(i))
      t=1./(1.+stvar(i)*0.2316419)
c Approximation is invalid for large negative standard
c variates
      if(stvar(i).lt.-3.) p(i)=1.0
      if(stvar(i).lt.-3.) goto 8
      ctot=c1*t+c2*t**2+c3*t**3+c4*t**4+c5*t**5
      p(i)=exp(-.5*stvar(i)**2)/sqrt(6.283185308)*ctot
C ACCOUNT FOR ROUND OFF ERROR IN THE APPROXIMATION
 8     continue
      if(p(i).gt.1.0) p(i)=1.0
      if(p(i).lt.0.0) p(i)=0.0
C CALCULATE THE STRUCTURAL SCORE "S"
       s(i)=-1.*alog10(p(i))
 5    continue
C FIND WHERE STRUCTURAL SCORE BECOMES NEGATIVE
        marker=0
      do 6 j=1,4
      temp=alog10(s(j))
       if(temp.le.0.0) marker=j
       if (temp.le.0.0) goto 10
       y(j)=alog10(temp)
 6     continue
       goto 11
 10    continue
 11    continue
       n=4
       if(marker.ne.0) n=marker-1
C REGRESS LOG(S) AGAINST PGA
      call regress(pga,y,n,ascor,bscor)
       call finscr(ascor,bscor,nehrp,score)
       sfinal(nehrp)=score
 510   format(' a=',f10.3,'b= ',f10.3)
 204   format(' x=',f8.5,'p=',f8.5,'s=',f8.5)
 50    continue
       xl=.5*nint((sfinal(1)+sfinal(2))/(2*.5))
       xm=.5*nint((sfinal(3)+sfinal(4)+sfinal(5))/(3*.5))
       xh=.5*nint((sfinal(6)+sfinal(7))/(2*.5))
       xm2=.5*nint((sfinal(3)+sfinal(4))/(2*.5))
       xh2=.5*nint((sfinal(5)+sfinal(6)+sfinal(7))/(3*.5))
200   format(' ',10a4)
```

Figure B2

```
     FORTRAN PROGRAM NEHRP.FOR
     PAGE 3
210  format(' ',5A4,7(f5.1),3x,3f5.1,3x,2f5.1)
     write(6,210)
     (bldg(i),i=1,5),(sfinal(i),i=1,7),xl,xm,xh,xm2,xh2
     return
     end
c-----------------------------------------------------------
c SUBROUTINE TO CALCULATE THE FINAL SCORE FOR EA NEHRP AREA
c-----------------------------------------------------------
      subroutine finscr(a,b,narea,score)
      dimension epa(7),s(7)
      data epa/.05,.05,.1,.15,.2,.3,.4/
      do 1 i=1,7
       s(i)=10**(10**(a+b*epa(i)*4/3))
    1 continue
      score=s(narea)
 200  format(' nehrp area',7(i5,1x))
 210  format(' score     ',7(f5.2,1x))
      return
       end
c--------------------------------------------------
C SUBROUTINE TO PERFORM LINEAR REGRESSION AND PROVIDE THE
C RESULTING CONSTANTS
c--------------------------------------------------
      subroutine regres(x,y,n,a,b)
      dimension x(10),y(10)
 500 format(' x',10f10.6)
 501 format(' y',10f10.6)
      sumx=0.0
      sumxy=0.0
      sumy=0.0
      sumx2=0.0
      do 1 i=1,n
      sumx=sumx+x(i)
      sumx2=sumx2+x(i)**2
      sumy=sumy+y(i)
      sumxy=sumxy+x(i)*y(i)
 1    continue
      b=(sumxy-sumx*sumy/n)/(sumx2-sumx*sumx/n)
      a=(sumy-b*sumx)/n
      return
      end
```

Figure B2

36

WOOD FRAME - LR
1 1 .8 .8 .87 1 1

6	0.20	0.80	2.60
7	0.70	1.50	4.80
8	1.80	4.70	11.00
9	4.50	9.20	19.70
10	8.80	19.80	39.70
11	14.40	24.40	47.30
12	23.70	37.30	61.30

LIGHT METAL
.9 .9 .9 .8 .77 .83 1

6	0.01	0.40	1.60
7	0.50	1.10	2.70
8	0.90	2.10	5.70
9	2.10	5.60	10.50
10	6.00	12.90	23.50
11	9.80	22.30	34.40
12	17.60	31.30	44.00

URM - LR
.9 .9 .82 1 1 1 1

6	0.90	3.10	7.50
7	3.30	10.10	26.40
8	8.90	22.50	48.50
9	22.10	41.60	74.90
10	41.90	64.60	93.60
11	57.20	78.30	97.30
12	72.70	89.60	100.0

URM - MR
.9 .9 .82 1 1 1 1

6	1.20	4.60	10.90
7	2.60	11.40	31.30
8	12.70	28.80	55.00
9	28.80	51.40	77.30
10	45.80	71.70	94.80
11	62.00	83.00	98.30
12	74.90	91.10	100.0

TILT UP
.5 .5 .85 .68 .77 .7 1

6	0.40	1.50	4.20
7	1.80	4.20	9.60
8	4.00	10.60	18.20
9	9.10	18.50	31.60
10	15.20	28.70	49.20
11	25.60	45.00	69.40
12	35.60	62.50	80.20

BR STL FRAME -LR
.53 .53 .85 .7 .91 .87 1

6	0.01	0.60	2.40
7	0.40	1.80	5.00
8	1.20	5.10	10.30
9	4.60	10.10	18.70
10	7.90	15.80	27.40
11	13.90	27.00	43.40
12	19.60	38.80	53.90

BR STL FRAME -MR
.53 .53 .85 .7 .91 .87 1

6	0.01	0.80	2.90
7	0.40	5.80	6.50
8	2.20	7.00	13.50
9	6.20	11.90	22.10
10	10.50	20.40	32.80
11	17.00	30.10	49.60
12	23.00	41.80	62.40

BR STL FRAME -HR
.53 .53 .85 .7 .91 .87 1

6	0.01	0.90	4.90
7	0.70	5.40	10.20
8	3.90	10.20	21.80
9	10.00	17.70	26.10
10	14.40	22.80	40.30
11	20.60	37.80	61.20
12	27.60	50.50	77.50

STL PERIM. MRF -LR
.5 .5 .85 .7 .8 1 1

6	0.01	0.70	2.20
7	0.50	1.70	3.90
8	2.00	3.80	7.90
9	3.70	7.20	11.50
10	6.90	13.90	20.90
11	10.10	22.20	32.20
12	16.80	31.40	44.10

STL PERIM. MRF -MR
.5 .5 .85 .7 .8 1 1

6	0.01	0.70	2.50
7	0.70	2.10	5.10
8	1.60	4.40	9.80
9	4.30	8.90	15.80
10	8.00	15.70	24.60
11	12.00	28.20	40.30
12	17.10	36.40	51.10

STL PERIM. MRF -HR
.5 .5 .85 .7 .8 1 1

6	0.01	0.70	3.50
7	0.90	2.40	7.30
8	2.30	6.20	14.20
9	5.30	14.50	24.50
10	9.60	19.80	31.50
11	17.00	36.70	50.50
12	23.40	44.50	59.10

STL DISTRIB MRF-LR
.5 .5 .85 .7 .8 1 1

6	0.01	0.40	1.90
7	0.10	1.40	4.20
8	1.10	2.90	7.60
9	2.80	5.80	12.10
10	4.70	10.80	20.10
11	7.10	19.70	31.00
12	18.60	32.50	44.10

STL DISTRIB MRF-MR
.5 .5 .85 .7 .8 1 1

6	0.01	0.80	2.70
7	0.30	1.70	4.80
8	1.50	4.30	9.60
9	3.20	7.10	14.80
10	5.50	12.60	19.30
11	8.40	19.60	33.70
12	11.50	30.30	42.10

STL DISTRIB MRF-HR
.5 .5 .85 .7 .8 1 1

6	0.01	0.50	2.70
7	0.40	2.40	6.50
8	1.70	4.90	12.70
9	3.30	9.60	18.60
10	6.60	16.30	26.40
11	8.40	24.20	41.40
12	11.80	32.30	50.20

RCSW NO MRF - LR
.6 .6 .8 .65 .91 .97 1

6	0.10	0.50	1.90
7	0.80	2.80	6.30
8	2.60	6.60	12.50
9	5.60	13.00	22.00
10	11.50	23.60	34.10
11	20.20	35.50	51.20
12	31.30	47.60	61.90

RCSW NO MRF - MR
.6 .6 .8 .65 .91 .97 1

6	0.20	1.00	2.80
7	0.60	3.70	7.80
8	3.30	8.80	16.10
9	8.00	17.50	29.50
10	16.40	28.90	44.70
11	22.60	39.50	57.90
12	33.10	49.80	70.40

RCSW NO MRF - HR
.6 .6 .8 .65 .91 .97 1

6	0.20	1.20	3.00
7	1.00	5.60	10.90
8	4.10	11.80	21.40
9	10.50	24.80	39.00
10	26.10	37.70	57.70
11	36.90	54.00	75.00
12	48.30	67.10	88.20

URM INFILL - LR
.83 .83 .82 .78 .77 .85 1

6	0.20	1.70	6.80
7	1.70	5.80	18.90
8	3.60	14.10	36.60
9	11.60	28.50	58.40
10	21.50	44.00	79.40
11	32.60	60.20	95.40
12	47.20	76.10	99.99

URM INFILL - MR
.83 .83 .82 .78 .77 .85 1

6	0.60	3.40	10.30
7	1.80	8.20	23.20
8	7.20	20.60	40.30
9	14.50	33.60	58.80
10	25.60	47.30	80.40
11	41.60	68.00	94.80
12	60.30	80.70	99.20

URM INFILL - HR
.83 .83 .82 .78 .77 .85 1

6	1.30	4.80	14.70
7	2.30	11.00	28.00
8	8.70	23.50	48.40
9	18.70	43.90	67.40
10	33.60	56.20	89.80
11	44.80	68.90	99.99
12	60.40	76.90	99.99

ND RC MRF - LR
.45 .45 .8 .65 .83 .97 1

6	0.20	1.30	3.60
7	1.90	4.20	10.10
8	5.40	12.10	21.80
9	12.80	21.10	38.20
10	17.50	31.80	50.80
11	27.20	47.50	65.60
12	42.40	62.00	81.40

ND RC MRF - MR
.45 .45 .8 .65 .83 .97 1

6	0.40	1.70	3.90
7	2.50	5.10	14.80
8	5.70	13.00	25.70
9	13.70	26.50	45.50
10	21.40	35.70	58.00
11	33.50	51.90	74.20
12	47.80	67.40	92.60

ND RC MRF - HR
.45 .45 .8 .65 .83 .97 1

6	0.40	1.70	3.50
7	1.70	5.40	13.40
8	6.00	13.30	28.00
9	12.60	25.30	44.90
10	23.70	40.50	65.20
11	33.70	55.30	80.30
12	54.00	75.80	94.90

D RC MRF - LR
.45 .45 .8 .65 .83 .97 1

6	0.20	0.40	1.50
7	0.70	1.70	4.70
8	2.10	4.10	10.40
9	4.00	9.20	16.90
10	8.70	17.50	26.60
11	15.30	25.90	36.30
12	28.30	41.90	51.70

D RC MRF - MR
.45 .45 .8 .65 .83 .97 1

6	0.40	1.30	3.30
7	1.30	3.40	6.90
8	2.30	5.80	12.60
9	5.40	10.80	20.10
10	8.60	16.90	26.30
11	16.80	28.40	40.40
12	24.10	37.10	51.50

D RC MRF - HR
.45 .45 .8 .65 .83 .97 1

6	0.50	1.80	3.90
7	1.50	3.20	7.80
8	3.10	6.90	17.50
9	6.10	13.70	24.70
10	10.90	21.50	33.60
11	14.80	31.80	47.20
12	19.50	38.60	56.80

PC FRAME -LR
.35 .35 .9 .57 .83 .8 1

6	0.10	1.10	4.20
7	0.80	2.80	8.40
8	3.20	8.00	18.90
9	10.00	23.20	33.90
10	18.90	37.60	56.90
11	24.20	48.70	68.60
12	32.10	60.00	83.90

PC FRAME -MR
.35 .35 .9 .57 .83 .8 1

6	.001	1.10	4.90
7	1.10	3.40	10.10
8	3.30	8.40	21.60
9	10.50	27.20	34.50
10	24.20	43.10	62.90
11	29.30	53.70	78.30
12	35.70	68.70	93.70

PC FRAME - HR
.35 .35 .9 .57 .83 .8 1

6	.001	1.10	5.00
7	1.00	4.10	9.80
8	3.30	10.10	24.60
9	11.90	29.60	39.70
10	24.70	44.30	63.90
11	29.90	54.60	79.60
12	35.00	69.70	99.50

RM SW W/O MRF - LR
.35 .35 .9 .85 .91 .97 1

6	0.20	0.80	2.30
7	0.90	2.90	7.10
8	2.20	6.00	14.20
9	4.60	13.50	27.20
10	11.90	23.20	40.50
11	21.50	41.90	62.20
12	31.80	52.30	72.90

RM SW W/O MRF - MR
.35 .35 .9 .85 .91 .97 1

6	0.20	1.20	3.20
7	1.50	3.50	8.90
8	2.90	9.90	20.20
9	6.60	17.90	32.70
10	15.80	30.50	51.60
11	26.90	46.10	73.60
12	38.50	59.70	89.50

RM SW W/O MRF - HR
.35 .35 .9 .85 .91 .97 1

6	0.30	1.20	4.00
7	1.60	5.10	12.50
8	3.40	13.30	25.90
9	11.10	22.50	44.10
10	19.20	36.80	65.40
11	31.30	55.00	82.80
12	44.00	70.50	97.20

RM SW W/ MRF - LR
.35 .35 .9 .85 .91 .97 1

6	0.10	1.00	2.40
7	0.80	2.40	7.60
8	3.10	5.90	12.40
9	6.50	11.90	20.10
10	10.70	18.40	33.40
11	19.80	30.90	59.00
12	29.40	51.30	79.20

RM SW W/ MRF - MR
.35 .35 .9 .85 .91 .97 1

6	0.60	1.40	2.90
7	1.60	3.50	8.00
8	3.70	8.80	16.80
9	8.10	15.20	27.20
10	13.00	23.70	45.00
11	22.80	39.40	69.40
12	37.00	57.80	87.50

RM SW W/ MRF - HR
.35 .35 .9 .85 .91 .97 1

6	0.80	1.60	3.20
7	1.20	2.90	7.10
8	3.10	7.10	14.80
9	6.80	13.20	25.20
10	11.20	24.30	47.40
11	19.40	40.10	69.70
12	36.00	66.50	89.90

LONG SPAN
1 1 .9 .7 .83 1 1

6	0.01	0.30	1.60
7	0.20	1.10	5.50
8	1.00	4.00	10.60
9	3.60	9.00	17.20
10	7.60	16.10	33.00
11	16.00	29.70	45.90
12	27.50	45.70	62.50

Figure B2

added to the Basic Structural Hazard scores above, (or subtracted, depending on whether their effect was to decrease or increase the probability of major damage) the resulting modified score would approximate the probability of major damage given the presence of that factor.

The final list of performance modification factors applicable to the rapid visual screening methodology is:

Poor condition: deterioration of structural materials

Plan irregularities: buildings with reentrant corners and long narrow wings such as L, H, or E-shaped buildings

Vertical irregularities: buildings with major cantilevers, major setbacks, or other structural features that would cause a significant change in stiffness in the upper stories of the building

Soft story: structural features that would result in a major decrease in the lateral load resisting system's stiffness at one floor - typically at the ground floor due to large openings or tall stories for commercial purposes

Pounding: inadequate seismic clearance between adjacent buildings - to be applied only when adjacent building floor heights differ so that building A's floors will impact building B's columns at locations away from B's floor levels and thus weaken the columns..

Large heavy cladding: precast concrete or stone panels that might be inadequately anchored to the outside of a building and thus cause a falling hazard (only applies to buildings designed prior to the adoption of the local ordinances requiring improved seismic anchorage).

Short columns: columns designed as having a full story height but which because of wall sections or deep spandrel beams between the columns have an effective height much less than the full story height. This causes brittle failure of the columns and potential collapse.

Torsion: corner or wedge buildings or any type of building in which the lateral load resisting system is highly non-symmetric or concentrated at some distance from the center of gravity of the building.

Soil profile: soil effects were treated by employing the UBC and NEHRP classification of "standard" soil profiles SL1, SL2 and SL3, where SL1 is rock, or stable soil deposits of sands, gravels or stiff clays less than 200 ft. in thickness; SL2 is deep cohesionless or stiff clay conditions exceeding 200 ft. in thickness; and SL3 is soft to medium stiff clays or sands, greater than 30 ft. in thickness. Present building code practice is to apply an increase in lateral load of 20% for SL2 profiles and 50% for SL3 profiles, over the basic design lateral load. This approach was used herein, and these factors were applied to the EPA for each NEHRP Map Area to determine the impact on the Basic Structural Hazard score. It was determined that this impact could generally be accounted for by a PMF of 0.3 for SL2 profiles, and 0.6 for SL3 profiles. Further, to account for resonance type effects, based on judgment the 0.6 PMF for SL3 profiles was increased to 0.8 if the building in questions was 8 to 20 stories in height.

Benchmark Year: year in which modern seismic design revisions were enforced by the local jurisdiction. Buildings built after this year are assumed to be seismically adequate unless exhibiting a major defect as discussed above.

Unbraced parapets, overhangs, chimneys and other non-structural falling hazards, while potentially posing life safety problems, do not cause structural collapse and therefore have not been assigned performance modifiers. Similarly, weak masonry foundations, unbraced cripple walls and houses not bolted to their foundations will cause significant structural damage but will probably not lead to structural collapse. Therefore the data collection form contains a section where this type of information may be noted, and the owner notified.

It was also determined that certain building types were not significantly affected by some of the factors. Therefore the modifiers do not apply to all building types. The actual values of the PMFs, specific to each NEHRP Map Area, may be seen on the data collection forms, Figures B3a,b,c.

ATC-21/ (NEHRP Map Areas 1,2 Low)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ____________________

____________________ Zip ________

Other Identifiers ____________________

No. Stories ________ Year Built ________

Inspector ________ Date ________

Total Floor Area (sq. ft) ________

Building Name ____________________

Use ____________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY

Residential	No. Persons
Commercial	0–10
Office	11–100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**8.5**	**3.5**	**2.5**	**6.5**	**4.5**	**4.0**	**4.0**	**3.0**	**3.5**	**2.5**	**4.0**	**2.5**
High Rise	N/A	0	0	N/A	-0.5	-0.5	-0.5	-0.5	N/A	-1.0	-1.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-1.0
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8

FINAL SCORE

COMMENTS

ATC1BLOW
30032.01

Detailed Evaluation Required?

YES NO

Figure B3a

ATC-21/ (NEHRP Map Areas 3,4, Moderate)

Rapid Visual Screening of Seismically Hazardous Buildings

Address ______________________

______________________ Zip ____________

Other Identifiers ______________________

No. Stories ____________ Year Built ____________

Inspector ____________ Date ____________

Total Floor Area (sq. ft) ______________________

Building Name ______________________

Use ______________________

(Peel-off label)

INSTANT PHOTO

Scale:

OCCUPANCY	
Residential	No. Persons
Commercial	0–10
Office	11–100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	6.0	4.0	3.0	6.0	4.0	3.0	3.5	2.0	3.5	2.0	3.5	2.0
High Rise	N/A	-1.0	-0.5	N/A	-1.0	-0.5	-1.0	-1.0	N/A	0	-0.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-1.0
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8

FINAL SCORE

COMMENTS

ATC24CMD
30003.01

Detailed Evaluation Required?

YES NO

Figure B3b

ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings

Scale:

Address ______________________________

______________________ Zip __________

Other Identifiers ______________________

No. Stories ______________ Year Built __________

Inspector ______________________ Date __________

Total Floor Area (sq. ft) ______________________

Building Name ______________________

Use ______________________

(Peel-off label)

INSTANT PHOTO

OCCUPANCY

	No. Persons
Residential	0–10
Commercial	11–100
Office	100+
Industrial	
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**4.5**	**4.5**	**3.0**	**5.5**	**3.5**	**2.0**	**3.0**	**1.5**	**2.0**	**1.5**	**3.0**	**1.0**
High Rise	N/A	-2.0	-1.0	N/A	-1.0	-1.0	-1.0	-0.5	N/A	-0.5	-1.0	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5
Soft Story	-1.0	-2.5	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE												

COMMENTS

ATC87M
30032.01

Detailed Evaluation Required?

YES NO

Figure B3c

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APPENDIX C

CRITERIA FOR SELECTION OF A CUT-OFF SCORE

Because the final Structural Score S can be directly related to the probability of major damage, the field survey building S scores can be employed in an approximate cost-benefit analysis of costs of detailed review versus benefits of increased seismic safety, as a guide for selection of a cut-off S appropriate for a particular jurisdiction.

As a preliminary guide to an appropriate cut-off value of S, note that an S of 1 indicates a probability of major damage of 1 in 10, given the occurrence of ground motions equivalent to the Effective Peak Acceleration (EPA) for the particular NEHRP Map Area. S =2 corresponds to a probability of 1 in 100, S =3 is 1 in 1000, and so on.

As a simple example, take a jurisdiction with a population of 10,000 and a corresponding building inventory of 3,000 wood frame houses and 100 tilt-up, 100 LR URM, and 10 mid-rise steel-framed buildings. Assume the jurisdiction is in NEHRP Map Area 6, and the Basic Structural Hazard scores of Appendix B, High seismic area, apply. Assume for the example that no penalties apply (in actuality, the penalties of course would discriminate the good structures from the bad). The building inventories, probabilities of major damage and corresponding mean number of buildings sustaining major damage are shown in Table C1.

Table C1

Type	No. Bldgs.	S	Prob. Major Damage	Expected No. Bldgs. With Major Damage
Wood	3,000	4.5	1/31,600	Approx. 0
Tilt-up	100	2.0	1/100	Approx. 1
URM	100	1.0	1/10	Approx. 10
Br. Steel Fr.	100	3.0	1/1000	Approx. 0

Given these results, this example jurisdiction might decide that a cut-off S of between 1 and 2 is appropriate. A jurisdiction ten times larger (i.e., 100,000 population, everything else in proportion) in the same Map Area might decide that the potential life loss in a steel-framed mid-rise (1,000 mid-rise buildings instead of 10) warrants the cut-off S being between 2 and 3. Different cut-off S values for different building or occupancy types might be warranted.

Ideally, each community should engage in some consideration of the costs and benefits of seismic safety, and decide what S is an appropriate "cut-off" for their situation. Because this is not always possible, the observation that research has indicated (NBS, 1980; see references in Appendix B) that:

> "In selecting the target reliability it was decided, after carefully examining the resulting reliability indices for the many design situations, that $\beta = 3$ is a

> representative average value for many frequently used structural elements when they are subjected to gravity loading, while $\beta = 2.5$ and $\beta = 1.75$ are representative values for loads which include wind and earthquake, respectively".

(where β, the structural reliability index, as used in the National Bureau of Standards study, is approximately equivalent to S as used herein) is provided.

That is, present design practice is such that an S of about 3 is appropriate for day-to-day loadings, and a value of about 2 or somewhat less is appropriate for infrequent but possible earthquake loadings.

It is possible that communities may decide to assign a higher cut-off score for more important structures such as hospitals, fire and police stations and other buildings housing emergency services. However, social function has not been discussed in the development of the scoring system for this RSP. This will be addressed in a future FEMA publication tentatively entitled "Handbook for Establishing Priorities for Seismic Retrofit of Buildings." Until and unless a community considers the cost-benefit aspects of seismic safety for itself, a preliminary value to use in an RSP, would be an S of about 2.0.

APPENDIX D

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APPENDIX E

ATC PROJECT AND REPORT INFORMATION

One of the primary purposes of Applied Technology Council is to develop resource documents that translate and summarize research information into forms useful to practicing engineers. This includes the development of guidelines and manuals, as well as the development of research recommendations for specific areas determined by the profession. ATC is not a code development organization, although several of the ATC project reports serve as resource documents for the development of codes, standards and specifications.

A brief description of several major completed and ongoing projects is given in the following section. Funding for projects is obtained from government agencies and tax-deductible contributions from the private sector.

ATC-1: This project resulted in five papers which were published as part of *Building Practices for Disaster Mitigation*, Building Science Series 46, proceedings of a workshop sponsored by the National Science Foundation (NSF) and the National Bureau of Standards (NBS). Available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, as NTIS report No. COM-73-50188.

ATC-2: The report, *An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings*, was funded by NSF and NBS and was conducted as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation. Available through the ATC office. (270 pages)

> *Abstract*: This study evaluated the applicability and cost of the response spectrum approach to seismic analysis and design that was proposed by various segments of the engineering profession. Specific building designs, design procedures and parameter values were evaluated for future application. Eleven existing buildings of varying dimensions were redesigned according to the procedures.

ATC-3: The report, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (ATC-3-06), was funded by NSF and NBS. The second printing of this report, which included proposed amendments, is available through the ATC office. (505 pages plus proposed amendments)

> *Abstract*: The tentative provisions in this document represent the result of a concerted effort by a multidisciplinary team of 85 nationally recognized experts in earthquake engineering. The project involved representation from all sections of the United States and had wide review by affected building industry and regulatory groups. The provisions embodied several new concepts that were significant departures from existing seismic design provisions. The second printing of this document contains proposed amendments prepared by a joint committee of the Building Seismic Safety Council (BSSC) and the NBS; the proposed amendments were published separately by BSSC and NBS in 1982.

ATC-3-2: The project, *Comparative Test Designs of Buildings Using ATC-3-06 Tentative Provisions*, was funded by NSF. The project consisted of a study to develop and plan a program for making comparative test designs of the ATC-3-06 Tentative Provisions. The project report was written to be used by the Building Seismic Safety Council in its refinement of the ATC-3-06 Tentative Provisions.

ATC-3-4: The report, *Redesign of Three Multistory Buildings: A Comparison Using ATC-3-06 and 1982 Uniform Building Code Design Provisions*, was published under a grant from NSF. Available through the ATC office (112 pages)

> *Abstract*: This report evaluates the cost and technical impact of using the 1978 ATC-3-06 report, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, as amended by a joint committee of the Building Seismic Safety Council and the National Bureau of Standards in 1982. The evaluations are based on studies of three existing California buildings redesigned in accordance with the ATC-3-06 Tentative Provisions and the 1982 Uniform Building Code. Included in the report are recommendations to code implementing bodies.

ATC-3-5: This project, *Assistance for First Phase of ATC-3-06 Trail Design Program Being Conducted by the Building Seismic Safety Council*, was funded by the Building Seismic Safety Council and provided the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the first phase of its Trial Design Program. The first phase provided for trial designs conducted for buildings in Los Angeles, Seattle, Phoenix, and Memphis.

ATC-3-6: This project, *Assistance for Second Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council*, was funded by the Building Seismic Safety Council and provided the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the second phase of its Trial Design Program. The second phase provided for trial designs conducted for buildings in New York, Chicago, St. Louis, Charleston, and Fort Worth.

ATC-4: The report, *A Methodology for Seismic Design and Construction of Single-Family Dwellings*, was published under a contract with the Department of Housing and Urban Development (HUD). Available through HUD. 451 7th Street S.W., Washington, DC 20410, as Report No. HUD-PDR-248-1. (576 pages)

> *Abstract*: This report presents the results of an in-depth effort to develop design and construction details for single-family residences that minimize the potential economic loss and life-loss risk associated with earthquakes. The report: (1) discusses the ways structures behave when subjected to seismic forces, (2) sets forth suggested design criteria for conventional layouts of dwellings constructed with conventional materials, (3) presents construction details that do not require the designer to perform analytical calculations, (4) suggests procedures for efficient plan-checking, and (5) presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

ATC-4-1: The report, *The Home Builders Guide for Earthquake Design* (June 1980), was published under a contract with HUD. Available through the ATC office. (57 pages)

> *Abstract*: This report is a 57-page abridged version of the ATC-4 report. The concise, easily understood text of the Guide is supplemented with illustrations and 46 construction details. The details are provided to ensure that houses contain structural features which are properly positioned, dimensioned and constructed to resist earthquake forces. A brief description is included on how earthquake forces impact on houses and some precautionary constraints are given with respect to site selection and architectural designs.

ATC-5: The report, *Guidelines for Seismic*

Design and Construction of Single-Story Masonry Dwellings in Seismic Zone 2, was developed under a contract with HUD. Available through the ATC office.

Abstract: The report offers a concise methodology for the earthquake design and construction of single-story masonry dwellings in Seismic Zone 2 of the United States, as defined by the 1973 Uniform Building Code. The guidelines are based in part on shaking table tests of masonry construction conducted at the University of California at Berkeley Earthquake Engineering Research Center. The report is written in simple language and includes basic house plans, wall evaluations, detail drawings, and material specifications.

ATC-6: The report, *Seismic Design Guidelines for Highway Bridges*, was published under a contract with the Federal Highway Administration (FHWA). Available through the ATC office. (210 pages)

Abstract: The Guidelines are the recommendations of a team of sixteen nationally recognized experts that included consulting engineers, academics, state and federal agency representatives from throughout the United States. The Guidelines embody several new concepts that are significant departures from existing design provisions. An extensive commentary and an example demonstrating the use of the Guidelines are included. A draft of the Guidelines was used to seismically redesign 21 bridges and a summary of the redesigns is also included.

ATC-6-1: The report, *Proceedings of a Workshop on Earthquake Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (625 pages)

Abstract: The report includes 23 state-of-the-art and state-of-practice papers on earthquake resistance of highway bridges. Seven of the twenty-three papers were authored by participants from Japan, New Zealand and Portugal. The Proceedings also contain recommendations for future research that were developed by the 45 workshop participants.

ATC-6-2: The report, *Seismic Retrofitting Guidelines for Highway Bridges*, was published under a contract with FHWA. Available through the ATC office. (220 pages)

Abstract: The Guidelines are the recommendations of a team of thirteen nationally recognized experts that included consulting engineers, academics, state highway engineers, and federal agency representatives. The Guidelines, applicable for use in all parts of the U.S., include a preliminary screening procedure, methods for evaluating an existing bridge in detail, and potential retrofitting measures for the most common seismic deficiencies. Also included are special design requirements for various retrofitting measures.

ATC-7: The report, *Guidelines for the Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (190 pages)

Abstract: Guidelines are presented for designing roof and floor systems so these can function as horizontal diaphragms in a lateral force resisting system. Analytical procedures, connection details and design examples are included in the Guidelines.

ATC-7-1: The report, *Proceedings of a Workshop on Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (302 pages)

Abstract: The report includes seven papers on state-of-the practice and two papers on recent research. Also included are recommendations for future research that were developed by the 35 participants.

ATC-8: This project, *Workshop on the Design of Prefabricated Concrete Buildings for Earthquake Loads*, was funded by NSF. Project report available through the ATC office. (400 pages)

Abstract: The report includes eighteen state-of-the-art papers and six summary papers. Also included are recommendations for future research that were developed by the 43 workshop participants.

ATC-9: The report, *An Evaluation of the Imperial County Services Building Earthquake Response and Associated Damage*, was published under a grant from NSF. Available through the ATC Office. (231 pages)

Abstract: The report presents the results of an in-depth evaluation of the Imperial County Services Building, a 6-story reinforced concrete frame and shear wall building severely damaged by the October 15, 1979 Imperial Valley, California, earthquake. The report contains a review and evaluation of earthquake damage to the building; a review and evaluation of the seismic design; a comparison of the requirements of various building codes as they relate to the building; and conclusions and recommendations pertaining to future building code provisions and future research needs.

ATC-10: This report, *An Investigation of the Correlation Between Earthquake Ground Motion and Building Performance*, was funded by the U.S. Geological Survey. Available through the ATC office. (114 pages)

Abstract: The report contains an in-depth analytical evaluation of the ultimate or limit capacity of selected representative building framing types, a discussion of the factors affecting the seismic performance of buildings, and a summary and comparison of seismic design and seismic risk parameters currently in widespread use.

ATC-10-1: This report, *Critical Aspects of Earthquake Ground Motion and Building Damage Potential*, was co-funded by the USGS and the NSF. Available through the ATC office. (259 pages)

Abstract: This document contains 19 state-of-the-art papers on ground motion, structural response, and structural design issues presented by prominent engineers and earth scientists in an ATC seminar. The main theme of the papers is to identify the critical aspects of ground motion and building performance that should be considered in building design but currently are not. The report also contains conclusions and recommendations of working groups convened after the Seminar.

ATC-11: The report, *Seismic Resistance of Reinforced Concrete Shear Walls and Frame Joints: Implications of Recent Research for Design Engineers*, was published under a grant from NSF. Available through the ATC office. (184 pages)

Abstract: This document presents the results of an in-depth review and synthesis of research reports pertaining to cyclic loading of reinforced concrete shear walls and cyclic loading of joints in reinforced concrete frames. More than 125 research reports published since 1971 are reviewed and evaluated in this report, which was prepared via a consensus process that involved numerous experienced design professionals from throughout the U.S. The report contains reviews of current and past design practices, summaries of research developments, and in-depth discussions of design implications of recent research results.

ATC-12: This report, *Comparison of United States and New Zealand Seismic Design Practices for Highway Bridges*, was published under a grant from NSF. Available through the ATC office (270 pages).

Abstract: The report contains summaries of all aspects and innovative design procedures used in New Zealand as well as comparisons of United States and New Zealand design practice. Also included are research recommendations developed at a 3-day workshop in New Zealand attended by 16 U.S. and 35 New Zealand bridge design engineers and researchers.

ATC-12-1: This report, *Proceedings of Second Joint U.S.-New Zealand Workshop on Seismic Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office (272 pages).

Abstract: This report contains written versions of the papers presented at this 1985 Workshop as well as a list and prioritization of workshop recommendations. Included are summaries of research projects currently being conducted in both countries as well as state-of-the-practice papers on various aspects of design practice. Topics discussed include bridge design philosophy and loadings, design of columns, footings, piles, abutments and retaining structures, geotechnical aspects of foundation design, seismic analysis techniques, seismic retrofitting, case studies using base isolation, strong-motion data acquisition and interpretation, and testing of bridge components and bridge systems.

ATC-13: The report, *Earthquake Damage Evaluation Data for California*, was developed under a contract with the Federal Emergency Management Agency (FEMA). Available through the ATC office (492 pages).

Abstract: This report presents expert-opinion earthquake damage and loss estimates for existing industrial, commercial, residential, utility and transportation facilities in California. Included are damage probability matrices for 78 classes of structures and estimates of time required to restore damaged facilities to pre-earthquake usability. The report also describes the inventory information essential for estimating economic losses and the methodology used to develop the required data.

ATC-14: The report, *Evaluating the Seismic Resistance of Existing Buildings*, was developed under a grant from the National Science Foundation. Available through the ATC office (370 pages).

Abstract: This report, written for practicing structural engineers, describes a methodology for performing preliminary and detailed building seismic evaluations. The report contains a state-of-practice review; seismic loading criteria; data collection procedures; a detailed description of the building classification system; preliminary and detailed analysis procedures; and example case studies, including non-structural considerations.

ATC-15: This report, *Comparison of Seismic Design Practices in the United States and Japan*, was published under a grant from NSF. Available through the ATC office (317 pages).

Abstract: The report contains detailed technical papers describing current design practices in the United States and Japan as well as recommendations emanating from a joint U.S.-Japan workshop held in Hawaii in March, 1984. Included are detailed descriptions of new seismic design methods for buildings in Japan and case studies of the design of specific buildings (in both countries). The report also contains an overview of the history and objectives of the Japan Structural Consultants Association.

ATC-15-1: The report, *Proceedings of Second U.S.-Japan Workshop on Improvement of Building Seismic Design and Construction Practices*, was published under a grant from NSF. Available through ATC office (412 pages).

> *Abstract:* This report contains 23 technical papers presented at this San Francisco workshop in August of 1986 by practitioners and researchers from the U.S. and Japan. Included are state-of-the-practice papers and case studies of actual building designs and information on regulatory, contractual, and licensing issues.

ATC-16: This project, *Development of a 5-Year Plan for Reducing the Earthquake Hazards Posed by Existing Nonfederal Buildings*, was funded by FEMA and was conducted by a joint venture of ATC, the Building Seismic Safety Council and the Earthquake Engineering Research Institute. The project involved a workshop in Phoenix, Arizona, where approximately 50 earthquake specialists met to identify the major tasks and goals for a 5-year plan for reducing the earthquake hazards posed by existing nonfederal buildings nationwide. The plan was developed on the basis of nine issue papers presented at the workshop and workshop working group discussions. The Workshop Proceedings and Five-Year Plan are available through the Federal Emergency Management Agency, 500 "C" Street, S. W., Washington, D.C. 20472.

ATC-17: This report, *Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation*, was published under a grant from NSF. Available through the ATC office (478 pages).

> *Abstract*: The report contains 42 papers describing the state-of-the-art and state-of-the-practice in base-isolation and passive energy-dissipation technology. Included are papers describing case studies in the Untied States, applications and developments worldwide, recent innovations in technology development, and structural and ground motion design issues. Also included is a proposed 5-year research agenda that addresses the following specific issues: (1) strong ground motion; (2) design criteria; (3) materials, quality control, and long-term reliability; (4) life cycle cost methodology; and (5) system response.

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